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WILLAMETTE RIVER BASIN WATER QUALITY CONTROL AND MANAGEMENT

James M. Quigley

Federal Water Pollution Control Administration
Portland, Oregon

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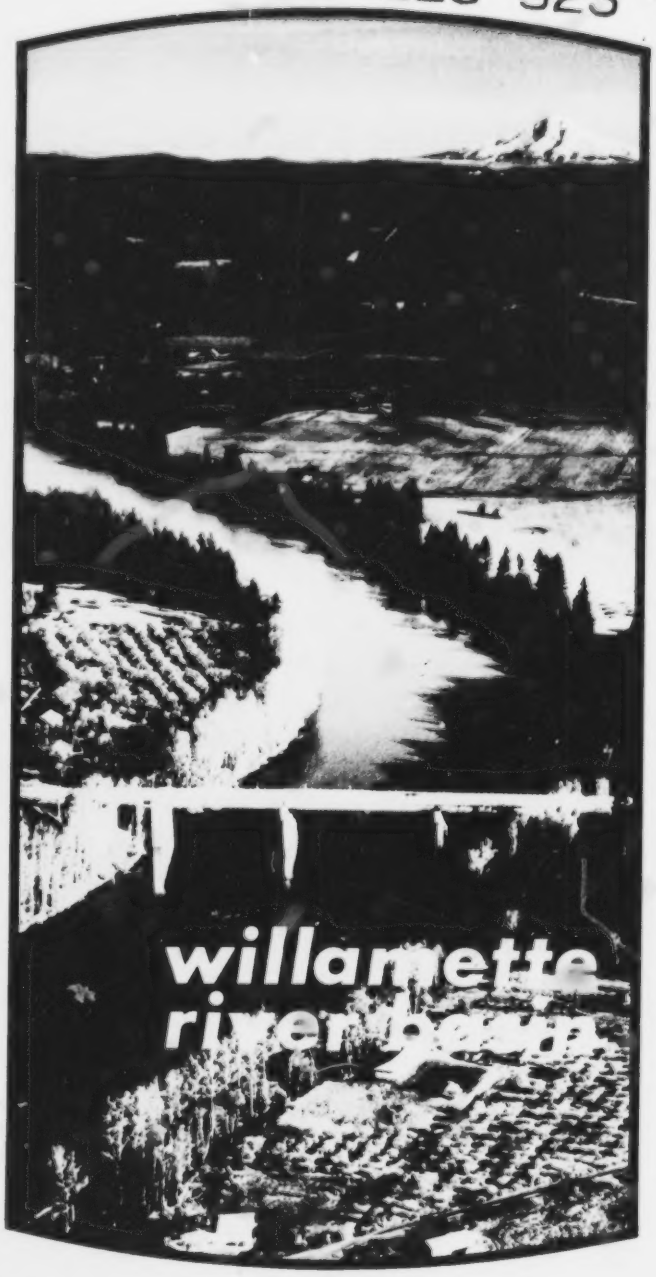

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A COMPREHENSIVE POLLUTION CONTROL PROGRAM DEVELOPED BY THE FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

RIVER BASIN STUDIES BRANCH

willamette river basin

WATER QUALITY CONTROL AND MANAGEMENT

JANUARY 1967

UNITED STATES DEPARTMENT OF THE INTERIOR

Federal Water Pollution Control Administration

Northwest Region, Portland, Oregon

FOREWORD

JAMES M. QUIGLEY, *Commissioner*
Federal Water Pollution Control Administration
U.S. Department of the Interior

Each summer the Willamette River becomes polluted. This splendid river, whose watershed supports two-thirds of Oregon's population and provides an equal proportion of its industrial output, suffers recurrently from massive outpourings of untreated industrial wastes. The effects of this pollution have been severe. The Willamette has largely been rejected as a source of water supply, and communities along its banks have had to develop other, and more costly, sources. Recreation has been curtailed, with many parks posted against swimming and the whole river below the city of Eugene exceeding Pacific Northwest Pollution Control Council bacterial objectives for water-contact recreation. Fish production has declined, as the natural habitat for trout has shrunk, and as passage conditions and spawning areas for that large portion of the Pacific salmon run that is based upon the Willamette have deteriorated with the persistence of pollution.

These conditions have existed for more than three decades. Gradual progress has been made in pollution abatement as a result of institution of waste treatment and summer flow augmentation from Federal storage reservoirs; but at the same time the magnitude of pollution sources has advanced. Industrial expansion, population growth, and urbanization have all acted to increase wastes and to offset much of the progress has occurred.

In 1961 the Water Supply and Pollution Control Division of the Public Health Service began a comprehensive study of water quality in the Columbia River Basin. The study, continued under the Federal Water Pollution Control Administration, has included considerable emphasis on the Willamette Basin, since it contains the clearest and most significant instances of water pollution found in the Columbia River Basin. This report contains a detailed analysis of the nature and extent of pollution, its cause, what may be done to abate it and prevent its recurrence, and what it will cost to control it.

The course of action recommended in this report is based upon the decision of the people of Oregon—a decision manifested by the repeated pronouncements of its public officials and by legislative enactments going back to the Act of 1938 creating a state agency with responsibility for control of water pollution—that the waters of the Willamette system are to be fit habitats for salmonid fish, suitable sources of recreation, and usable water supplies. These are demanding goals, in terms of water quality, but no lesser goals have ever been publicly advanced. Unfortunately the public and private actions needed to fulfill these goals have not always been forthcoming. This report sets forth a plan for such actions. Whether this plan will achieve its purpose is also a decision which rests largely with the people of Oregon.

willamette river basin

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INTRODUCTION

CHAPTER ONE

SUMMARY AND IMPLEMENTATION

Summarized in this chapter are the major findings which resulted from the comprehensive study of the Willamette Basin, the recommended measures to alleviate existing and anticipated pollution problems, and, finally, the means of implementing those measures--by whom and at what costs. Discussion of specific regions appears in Chapter Five.

conclusions:

1. One of the most serious water pollution problems that exists in the Pacific Northwest--in terms of impacts on use and volume of water affected--occurs in the lower Willamette River. Under low flow conditions, discharges of untreated industrial wastes by pulp and paper mills operated by Publishers Paper Company at Oregon City and at Newberg and by Crown Zellerbach Corporation at West Linn result in dissolved oxygen depression. The area of dissolved oxygen deficiency extends from a point below the confluence of the Clackamas River to the mouth of the Willamette. The affected portion of the river passes through the most densely populated part of Oregon and serves as the passageway for all migratory fish that spawn in the Willamette system.

2. With the exception of the seasonal depression of dissolved oxygen in the lower river, the quality of the waters of the Willamette River Basin is generally high. Dissolved oxygen is close to saturation through most of the river system, mineral concentrations are within Public Health Service drinking water standards, temperature of the main stem and east side tributaries is usually below seventy degrees (F) through the year, and levels of turbidity are generally low, except during the period of heavy winter rainfall. Undesirable water quality features other than the flow related oxygen deficiencies of the lower Willamette River and two tributaries, the Tualatin and South Santiam Rivers--include bacterial concentrations above acceptable levels for swimming through most of the Willamette River, and an increasing prevalence of Sphaerotilus and other slime-like growths, that is generally associated with industrial waste loads. Since a minor degree of regulation has been imposed upon the stream, storage capacity authorized for flood control, power, irrigation, and navigation is equal to only about a twelfth of the average annual runoff--flow drops to only 20 to 30 percent of average monthly levels during the critical dry summer months, resulting in critical localized oxygen deficiencies during drought years. Even in the average water year, a dry July, August, or September, will often produce, in the lower river, oxygen levels well below, and temperature levels well above, the limit of tolerance for migrating fish.

3. The critical water quality requirements of the Willamette River system arise out of its function as a spawning and rearing area for salmon. The system supplies about a quarter of the total Columbia River Basin production of spring chinook salmon, and substantial quantities of coho, steelhead, and lesser salmon varieties. The whole of the main stem serves as a passageway for these migratory fish, which supply commercial fisheries in the Columbia River and in the Pacific Ocean, as well as a local sport fishery. Other functions include municipal and industrial water supplies and various forms of water-based recreation. Meeting the quality criteria for these uses will also provide satisfactory water quality for other legitimate uses.

4. Oregon State agencies--primarily the OSSA and the OSWRB--have recognized the pollution control needs of the Willamette River Basin, and have adopted programs to protect water uses. These programs, however, have failed to end pollution of the Willamette River because of weaknesses in enforcement powers. The Sanitary Authority has issued water quality criteria and waste treatment requirements designed to satisfy the needs of the anadromous fishery. Treatment requirements are based on minimum streamflows which are to be provided for navigation in the Willamette River by operation of the completed system of multiple purpose reservoirs now authorized to be constructed by the U. S. Army Corps of Engineers in the Willamette River Basin. The Sanitary Authority has also called for, and largely achieved, secondary treatment of all municipal wastes, and has instructed the pulp mills which constitute the major source of pollution to adhere to a schedule of maximum allowable waste loads. The Water Resources Board has recognized the use criteria--including fish production, recreation, and water supply--which properly apply to the Willamette River Basin, and has recognized in principle the need for a base flow for the purpose of water quality maintenance.

5. Municipalities provide a high degree of waste reduction through treatment. With the exception of Albany and the largest city, Portland, every community with ten thousand or more inhabitants has installed or is installing secondary waste treatment facilities. The smaller towns have also provided secondary treatment, or equivalent waste stabilization ponds. Of a total municipal population that exceeds 365 thousand outside the city of Portland, all but about 28 thousand will soon be provided with secondary waste treatment or its equivalent; and only 350 persons in the village of Monroe have no waste treatment. Portland's wastes are collected by a master sewer system for primary treatment and discharge to the Columbia, rather than to the Willamette River. Portland's waste collection is, however, incomplete. An estimated 30,000 population equivalents of untreated wastes continue to flow from the city into the lower Willamette. Though urban runoff is not a critical factor in determining water quality conditions, the desirability of providing separate storm and sanitary sewers has been recognized by the OSSA whose policy it is to approve only separate sewer systems. There has been little effort, however, to separate existing combined systems.

6. Industrial waste treatment as a whole is less effective than municipal waste treatment, though most manufacturing plants provide some measure of treatment or control. The food processing industry generally provides a high level of waste reduction in many cases by channeling its wastes through municipal treatment plants. Dairies, plywood mills, and miscellaneous industries provide, as a group, an estimated 75 percent reduction in strength of their organic wastes. The pulp and paper industry, which is the largest source of wastes, its 4.5 million population equivalents of organic wastes amount to more than 60 percent of the basin's total, affords wide differences in waste reduction practices. The mills located in the southern half of the basin: Weyerhaeuser at Springfield, Western Kraft at Albany, and Crown Zellerbach at Lebanon, provide a high level of waste treatment. In the case of the Springfield and Albany sulfate mills, biochemical oxygen demand (BOD) removal efficiencies exceed the level obtained by effective secondary treatment of municipal wastes. The four sulfite pulping mills in the northern portion of the basin: Boise Cascade at Salem, Publishers Paper at Newberg and Oregon City, and Crown Zellerbach at West Linn, provide no waste treatment. These plants control wastes only to the extent of storing them during low flow periods for discharge during high flows, or, in the case of the Oregon City mill, transporting untreated wastes for discharge into the larger flows of the Columbia River. The OSSA has instructed the lower basin mills to install primary treatment facilities by the summer of 1968 and has established requirements, ranging from 85 to more than 90 percent, as to the level of BOD reduction which each mill is instructed to obtain by barging or waste storage during the critical season. As a result of an interstate conference on pollution of the lower Columbia River, it has been agreed that barging will be discontinued by 1970.

7. Water quality problems of the Willamette River Basin are largely associated with low flows. Precipitation occurs largely as rain and in the winter months, thus, the pattern of spring flood and extended flow which is characteristic of streams fed by snowmelt does not occur. Reservoir releases for navigation and power generation have helped to alleviate summer water quality problems associated with low flows. Such releases, however, are not guaranteed, nor are they provided in a schedule that meets specific pollution control requirements.

8. The industrial output and population of the Willamette River Basin have expanded at rates exceeding that of either the Nation as a whole or the Pacific Northwest over the last quarter century. For the most part, this growth has been concentrated along the main stem of the Willamette River in four urbanized and industrialized locations: Eugene-Springfield, Albany-Corvallis, Salem, and Portland. The high relative rate of growth and tendency to concentration are projected to continue into the future. Population of the basin is projected to increase from less than 1.2 million persons in 1960 to about 3.9 million by 2010, with the combined population of the four principal urbanized locations growing from roughly 78 percent of the 1960 population to over 85 percent of the larger population of 2010. Growth of output among major industries is expected to be even more marked in some cases. While lumber and plywood are expected to display little increase in volume of products, a higher degree of processing is expected to be incorporated into final output. Food processing is expected to expand fourfold. Tonnage of woodpulp is expected to increase about 175 percent, with conversion of pulp into products increasing at an even more marked rate.

9. Expansion of waste loads as a consequence of rapid economic growth will require inauguration of a sustained water quality management program if the high quality normally characterizing the waters of the river system is to be preserved. The prime need of such a program is immediate provision of a high level of waste treatment by the lower basin pulp and paper mills. This, with construction of other waste treatment facilities which are required if the region is to provide the adequate waste treatment to qualify for flow regulation from Federal reservoirs, will involve a capital expenditure estimated at $23.6 millions. Increasing the level of waste treatment, providing for expanding waste loads, and replacing facilities as they become obsolete will require additional capital expenditures estimated at $78.6 millions, by the year 1985. In addition to waste treatment, water quality maintenance in the Willamette River Basin will require flow from storage. Dry year flows are not sufficient to provide acceptable water quality, even with higher levels of waste treatment capabilities envisaged for the future. To provide, under once in ten year low-flow conditions, the base flow of 6,000 cfs at Salem that is computed to be required for maintenance of quality criteria, 584,000 acre-feet of storage, having a value of $141.2 millions, must be made available in Federal reservoirs. For the Willamette itself, this volume of storage may be provided out of either new reservoir construction or from reassignment of project purposes in existing reservoirs. In the cases of tributaries, however, sources of flow are limited, and allocation of storage from a single reservoir may be critical for water quality. Effective water quality management must also extend to land management practices, measures other than treatment which reduce waste loads at critical points, and development of more efficient treatment methods. To provide for the steadily increasing complexities of water quality management, systematic monitoring of stream quality, streamflow, and waste loads must be practiced, and legal standing must be accorded to streamflow for the express purpose of quality control.

RECOMMENDATIONS

IMMEDIATE POLLUTION ABATEMENT

1. The primary need for abatement of existing water pollution in the Willamette River Basin should be met by installation and operation of waste reduction facilities for pulping and papermaking that provide efficiencies equal to those of conventional secondary waste treatment: essential removal of floating and settleable solids and reduction of at least 85% of biochemical oxygen demand. Such facilities should be made available within the next five years at the plants operated by Publishers Paper Company at Oregon City and Newberg, Crown Zellerbach Corporation at West Linn and Lebanon, and Boise Cascade Corporation at Salem.

2. Effective secondary treatment should be installed within the next five years by those communities which do not provide or are not presently constructing such plants, and waste treatment facilities of communities operating plants that are outmoded or overloaded should be brought up to generally accepted standards for secondary treatment of waste. Communities that require secondary treatment are Albany, Cottage Grove, Harrisburg, Junction City, Monroe, and Oakridge. In the category of communities operating inadequate plants are Dallas, Mount Angel, McMinnville, Sweet Home, and the Fanno Creek Sanitary District.

3. The State of Oregon should proceed to adopt standards, as required by the Federal Water Pollution Control Act, for that portion of the Willamette River that is interstate water in that it is subject to tidal influences. Oregon standards for the major portion of the river that is intrastate should be compatible with the interstate standards, in the interest of protecting water uses and developing a firm and consistent pollution control program. Standards should clearly recognize the importance of the river system as a spawning area for anadromous salmonid fish and support the expansion of recreational and water supply capabilities of the basin's waters.

LONG TERM POLLUTION CONTROL

1. The State of Oregon should encourage and provide assistance in development of institutional arrangements that bring appropriate communities, industries, and metropolitan areas together for the purpose of planning and financing pollution control measures within the framework provided by drainage areas.

2. Reallocation of functions of the Federal reservoir system in the Willamette River Basin, to be considered in 1970 upon completion of a joint State of Oregon-Federal agencies study of water and related land resources of the basin, should recognize the overlapping benefits to water quality, fishery, and recreation that are obtainable with maintenance of summer base flows of at least 7,500 cubic feet per second through Portland harbor, 260 cubic feet per second in the lower Tualatin River, and 100 cubic feet per second in the South Santiam River below Lebanon.

3. The State of Oregon should establish limits for waste loads in intensively used watersheds. Such limits should reflect characteristics of wastes, minimum streamflow probabilities, and quality of waste control techniques available within the watershed.

4. Data gathering and monitoring activities of the Oregon State Sanitary Authority and of the Federal Water Pollution Control Administration should be coordinated and expanded to maintain intimate knowledge of waste loadings, treatment plant efficiencies, streamflows, and reservoir operations, in order that such information may be utilized in mathematical simulations of the river system as planning tools and instruments of day-to-day water quality management.

5. Programs of Federal resource management agencies operating in the Willamette River Basin should be periodically reviewed by the Federal Water Pollution Control Administration for possible impacts on water quality, with the Federal Water Pollution Control Administration and the several agencies jointly developing and monitoring effects of procedures to avoid adverse impacts, and coordinating such programs with Oregon State and local watershed organizations' pollution control plans.

JULY 1965
IMMEDIATE POLLUTION ABATEMENT NEEDS

Catagory	Requirement	Location	Responsibility	Estimated Investment	Annual Cost Estimate to 1985
Waste Treatment	Primary	Lebanon	Crown Zellerbach		
	Primary & Recovery	Newberg	Publisners Paper		
	Primary & Recovery	Oregon City	Publishers Paper		
	Primary & Recovery	West Linn	Crown Zellerbach	$12,400,000	$ 600,000
	Primary	Salem	Boise Cascade		
	Primary	Albany	Western Kraft		
	Secondary	Albany	Municipality		
	Secondary	Corvallis***	Municipality		
	Secondary	Cottage Grove	Municipality		
	Secondary	Harrisburg	Municipality	11,200,000	1,000,000
	Secondary	Junction City	Municipality		
	Secondary	Monroe	Municipality		
	Secondary	Oakridge	Municipality		
Flow Regulation	60 cfs (10,400 A.F. of storage)	Tualatin R.	U.S.-Scoggins Cr. Project		
	100 cfs (3,540 A.F. of storage)	S. Santiam R.	U.S.-Green Peter Project	4,000,000 **	630,000
	7500 cfs (584,000 A.F. of storage)	Portland harbor	U.S.-Willamette Reservoirs		
Other Pollution Control Practices	Interceptor sewer	Portland harbor***	Portland	12,000,000	N.A.
Management Practices	Summer Sampling	River system	OSSA	-	30,000
	Water Pollution Surveillance Station	Corvallis	FWPCA	3,000	500
	Daily flow reporting and forecasting	Lower basin	USGS*	6,000	2,000
	Data gathering and analysis	Lower basin	FWPCA	-	5,000
	Evaluation of Federal programs	Basin-wide	FWPCA	-	5,000
	Training of Treatment Plant Operators	Basin-wide	OSSA-OSU	-	10,000
	Establishment of base flows	Basin-wide	OSWRB	1,000,000	-
	Sampling and reporting waste discharges	Basin-wide	OSSA	-	25,000

* *FWPCA funding*
** *Assuming no additional investment for flows assigned to navigation*
*** *Under construction July 1965*

Implementation Program

Controlling pollution in the Willamette River Basin in order to provide water quality sufficient to adequately serve the river system's functions of water supply, fish habitat, and recreation resource will require a coordinated program of waste reduction, flow regulation, application of waste controlling techniques, and the development of a system of cooperative management of the watershed for pollution control. The broad principles underlying such a program have been presented as recommendations. In the final chapter of this report, the application of the recommendations to specific subareas is outlined and justified. This portion of the report represents a summation of all of the measures that are felt to be necessary to preserve the water quality of the Willamette--specific statements as to what should be done, and by whom, together with a statement regarding the general nature of the priority of various requirements, and a generalized estimate of the investment and operating costs that will be required to sustain the envisaged program.

A compelling need is meaningful coordination of the activities of all of the agencies which have a responsibility within the program. Among these, the OSSA and the FWPCA are the paramount State and Federal agencies among the many groups having a regulatory or affective interest in pollution control in the Willamette River.

The major share of the responsibilities that are outlined fall upon the OSSA, which is the State of Oregon's regulatory arm in matters involving water pollution. But the well conceived and technically sound program of the OSSA can only be implemented through the actions of individual communities and industrial plants.

Within the framework of Oregon law, the OSPPB is responsible for determining what uses are to be made of the waters of the State. The responsibilities of the Board with respect to water quality, then, are significant, including both the establishment of base flows essential to quality control on heavily used streams, and synthesizing of the variety of water using interests into goals for water use which must ultimately determine water quality objectives.

Each of the private and public interests which is involved in land use that has an impact on water quality has a responsibility to develop and implement practices which limit polluting effects of their activities on water.

The FWPCA is responsible for obtaining, analyzing, and disseminating information regarding water quality, for advising all Federal water management agencies on necessary water management practices relevant to pollution control, for reviewing

grant applications involving waste treatment construction, and for providing modifications to the comprehensive plan for pollution control that will maintain its utility in the face of changing conditions.

WASTE TREATMENT

Waste reduction through effective treatment is the critical requirement for an effective water quality management program in the Willamette Basin.

The existing program of the OSSA calls for a high level of treatment for most waste sources. For waste loads discharged into the lower Willamette, an 85 percent reduction of waste discharges during the critical summer period is required. In the Tualatin River Basin, the Sanitary Authority has instructed that all municipalities must maintain secondary waste treatment that results in at least 90 percent waste reduction. Each of the basin's pulp and paper mills has been instructed to provide primary waste treatment, and to limit its waste discharges to a given level of biochemical oxygen demand during the critical period. Effectiveness of the program, however, rests strongly on waste storage--rather than treatment--for pulp mills, the principal source of wastes.

The single most necessary element in ending existing pollution of the Willamette River is immediate installation of primary waste treatment facilities at all pulp and paper mills which do not presently provide it, together with the provision of equipment to condense and burn, or otherwise dispose of, the sulfite waste liquors of pulp mills operated by Publishers Paper Company at Newberg and Oregon City and by Crown Zellerbach Corporation at West Linn. These plants, because of location, process, and lack of waste treatment, create the largest adverse impact on the quality of the Willamette River. In addition, those communities (largely located in the upper basin) which do not presently provide secondary treatment of their wastes should proceed to do so.

There are other waste treatment measures which are less immediately critical, but which will soon become necessary, and which should, in the interest of good practice, be initiated at the earliest possible date. Such measures include provision for condensation and burning of concentrated pulping liquors by the Boise Cascade Corporation pulp and paper mill at Salem, secondary treatment of the wastes of the Crown Zellerbach pulp and paper mill at Lebanon, and enlargement or replacement of municipal waste treatment plants whose capacity fails to meet existing demands.

Long-term waste treatment needs will impose a continuing requirement for treatment plant construction. The substantial growth of population and industrial output envisaged for the region will be a source of sustained pressure on treatment capabilities. Obsolescence of existing plants will become an increasingly significant source of treatment needs during the early 1980's when a large number of plants built in the late 1950's and early 1960's will require replacement. In some areas, higher degrees of treatment will have to be accomplished. Secondary treatment of all pulp and paper mill wastes will unquestionably become necessary during the next decade; and advanced waste treatment is fast becoming a necessity in the densely populated Tualatin River Basin.

Providing this physical plant will require a sustained program of investment by the communities and industries of the Willamette Basin. Accomplishment of a level of waste treatment required to abate existing pollution in Portland harbor will involve an estimated expenditure on the order of $23.6 millions, divided almost equally between municipalities and pulp and paper plants. While this level of expenditures should suffice to reduce the most immediate sources of pollution, another $5.5 millions will be required to: (1) bring all existing waste treatment plants up to an acceptable level of efficiency; (2) provide waste reduction measures equal to those required of other sulfite pulp mills for the Boise Cascade plant at Salem, and (3) provide secondary waste treatment to the wastes of the Lebanon pulp mill of Crown Zellerbach Corporation. Thus, a waste treatment investment of over $29 millions should be made by residents of the Willamette River Basin over the next five years. In addition to the construction and financing costs presented by these improvements, an annual increment to operation and maintenance costs for waste treatment facilities of about $1.7 million may be anticipated.

To maintain a proper level of treatment efficiency through necessary plant replacement and expansion, to provide the advanced waste treatment that will be required in the Tualatin River Basin as a result of population growth, and to extend secondary waste treatment to all of the pulp and paper mills, an additional investment of about $74 millions will be required by 1985. Operating and maintenance costs for this system of waste treatment plants may be expected to expand by another $4 millions a year by 1985.

In total, then, an investment in waste treatment amounting to about $104 million over two decades must be provided if the quality of the Willamette is to be restored and maintained. In addition to the average annual increment of more than $5 millions to depreciation and amortization expenses, operating and maintenance costs will rise by roughly the same amount. The incidence of costs will not be evenly distributed. Close to 30 percent must be made as soon as possible, in order to abate existing pollution. Another large proportion of the costs will appear in the 1980's, as the inventory of existing waste treatment plants is depleted by obsolescence.

Several points should be noted in assessing the magnitude of required waste treatment investments. A good portion of the immediate need has already been budgeted--by municipalities constructing and planning additions to treatment works, by pulp and paper mills preparing to meet the OSSA's instruction that they provide primary waste treatment, and by the Publishers Paper Company plant at Oregon City which has taken the first steps toward installing chemical recovery processes. Techniques exist to lessen treatment costs. These include the combination of treatment capabilities among communities and industries, and the installation of process controls that lessen waste volumes of industrial plants. Improvements in waste treatment technology which are presently being developed hold the prospect of lower unit costs as well as higher efficiencies: the assessment presented is no more than an estimate, in 1965 dollars, of the costs of providing effective waste treatment with the methods and organizational structure that presently prevail in the Willamette River Basin.

FLOW REGULATION

Waste treatment alone cannot provide the level of quality that is desired in the Willamette River Basin. Because of the association of pollution with depleted summer flows, augmentation of flow by regulated releases from basin reservoirs is a necessary concomitant of an effective pollution control program.

The Federal Water Pollution Control Act authorizes the allocation of storage on a non-reimbursable basis in Federal reservoirs, for the purpose of regulating flow for quality control. Two preconditions exist: First, the area receiving the benefits of such storage must provide adequate waste treatment--which has been interpreted to mean no less than the waste reduction equivalent of secondary treatment of sanitary wastes; second, the benefits of the quality increment achieved as a result of Federal storage must be widespread--that is, they must accrue to the inhabitants of the watershed, at the least, rather than to a limited interest group. Since water quality objectives proposed for the Willamette Basin are based in part on maintenance of a fishery of national importance, in part on recreational benefits that extend to all inhabitants and visitors to the Willamette Basin, the test imposed by "widespread benefits" is obviously met. Adequacy of treatment will be insured by adoption and implementation of this comprehensive program. Manifest flow regulation needs exist in the Portland harbor, the Tualatin River, the Yamhill River, the South Santiam River, the Pudding River, and Bickreall Creek.

The Tualatin River's need for augmented summer flows is perhaps the most immediate and pressing in the Willamette River Basin. The watershed of the Tualatin already provides an average level of waste reduction that exceeds 90 percent, yet dissolved oxygen in the lower river consistently drops well below the 5 mg/l required for fish passage; and other quality parameters present an equally dismal picture. Projections of population and industrial output indicate that by 1985 a flow of at least 260 cfs at and below Farmington will be required at all times if passage for fish runs is to be maintained. The calculations from which the flow requirement was derived assumed advanced waste treatment with 95 percent reduction of BOD. Given the flows that existed in the 1944 design year, 46,260 acre-feet of storage will be necessary to provide suitable water quality. The FWPCA has recommended that 10,400 acre-feet of storage for flow regulation for quality control be included in Scoggins Creek Reservoir. It is assumed that this amount of water available for flow regulation will serve to abate the existing pollution situation. Development of advanced waste treatment and additional storage from reservoir sites being studied on other tributaries of the Tualatin will be required if nuisance conditions are to be averted in the future along this waterbody marked by rapid population growth.

SUMMARY OF STORAGE REQUIREMENTS-TUALATIN RIVER

Month	Average 1944 Flow (cfs)	Supplemental Flow Required (cfs)	Draft-on-Storage (acre-feet)
July	101	159	9,540
August	55	205	12,300
September	50	210	12,800
October	83	187	11,900

The Yamhill River's flow regulation need is expected to rise largely as a result of a Federal water resource development project. Existing summer flows are more than sufficient to provide dissolved oxygen (DO) requirements under projections of 1985 development, with secondary treatment of organic wastes. The Red Prairie project of the U. S. Bureau of Reclamation, however, is expected to result in a wide increase in the use of the river for irrigation. Existing water rights, if exercised, would deplete the river's flow entirely. Calculations indicate that provision of DO concentrations of 5 mg/l in the lower river depends on maintenance of a flow of 35 cfs--with 85 percent reduction of organic wastes through treatment. (This percentage represents a high degree of treatment efficiency, since a good portion of the wastes of this predominantly agricultural valley are not susceptible to collection and treatment.) Because of the existing water rights, it may be assumed that the entire 35 cfs required to achieve quality objectives must be derived from Federal storage in the Red Prairie project. The proposed level of flow does not assume the development of a major food processing industry as a result of increased irrigation. Should such plants eventuate, the indicated flow could support quality objectives only through application of advanced waste treatment.

The South Santiam River's flow regulation requirements arise as a result of the waste discharges of a pulp and paper plant at Lebanon. The municipalities and industries along the river--including the pulp and paper plant--provide a high level of waste treatment; and the OSSA has instructed the pulp mill to limit its summer waste discharges to about 5 percent of the strength of its gross waste production. In spite of the high level of waste reduction, the lower river continues to suffer severe degradation of various quality elements as a result of attenuated summer flows. The negative influence on quality is extended to the main stem of the Santiam River. Calculations that assume maintenance of the Sanitary Authority's pulp mill waste discharge limit and secondary waste treatment by all other sources of wastes indicate that a flow of 100 cfs must be maintained below Lebanon in order to maintain a DO concentration of 5 mg/l. Under design year flow conditions, 3,540 acre-feet of storage is required to maintain the indicated base flow. Such storage could be provided in Green Peter Reservoir, which is being constructed by the U. S. Army Corps of Engineers.

SUMMARY OF STORAGE REQUIREMENTS
SOUTH SANTIAM RIVER

Month	Average 1944 Flow (cfs)	Supplemental Flow Required (cfs)	Draft-on-Storage (acre-feet)
July	202	none	none
August	83	37	2,220
September	100	none	none
October	78	22	1,320

Flow regulation on the *Pudding River* is required as a result of sluggish flow and diversions for irrigation rather than as a consequence of waste discharges. The few minor communities in the watershed all provide secondary waste treatment. With the exception of low dissolved oxygen and extreme temperature in its ultimate reach, the river is well suited to the rearing of salmonid fish. To obtain the 7 mg/l of DO requisite of a proper fish habitat, 55 cfs must flow through the river below Mount Angel. Storage required to maintain this level of flow under design year flow conditions amounts to 6,360 acre-feet. No storage is presently proposed for the Pudding River. Several possible sites are under study, however.

SUMMARY OF STORAGE REQUIREMENTS
PUDDING RIVER

Month	Average 1944 Flow (cfs)	Supplemental Flow Required (cfs)	Draft-on-Storage (acre-feet)
July	47	8	480
August	18	37	2,220
September	24	31	1,860
October	25	30	1,800

Rickreall Creek's existing flow regulation needs are similar to those envisaged for the Yamhill River. Irrigation demands deplete the stream in a dry year. A flow of 13 cfs is required to maintain fish passage requirements. The necessary flow has been recommended from the Monmouth-Dallas project of the Bureau of Reclamation, which involves pumping from the Willamette River. Because the stream is presently dry as a result of summer irrigation, the entire flow requirement would have to be provided by the project, indicating a need for the equivalent of 3,120 acre-feet of storage.

Portland harbor's needs are far more extensive than the other flow regulation proposals which have been presented. They are also far more complex, bound into the conflicting benefits and the operational schedules of reservoirs that came into being before water quality con-

would not have been met during the summers of five of the twenty-seven years--a frequency of failure of one in 5.4.

Under existing conditions, the frequency of failure is even greater. Since 1953--the year which marked completion of Detroit Reservoir, the last major impoundment to be built in the Willamette watershed--the flow requirement has been breached in seven months of five years. The frequency of failure in actual operation of the system, then, is one in 2.4 years.

Recognition of the water quality-serving function as well as the navigational function of a minimum flow of 6,000 cfs, and providing it with a firm status, would be the major Federal contribution to maintaining Willamette River water quality.

Based on the 1944 design year, flow of 6,000 cfs at Salem to provide a flow of 7,500 cfs at Portland, would require 584,000 acre-feet of storage in either existing Willamette Basin reservoirs, or proposed reservoirs, including those for which specific water quality flow regulation is recommended in this report.

SUMMARY OF STORAGE REQUIREMENTS
LOWER WILLAMETTE RIVER

Month	Average 1944 Flow (cfs)	Supplemental Flow Required (cfs)	Draft-on-Storage (acre-feet)
July	4,800	1,200	72,000
August	3,230	2,770	166,000
September	3,150	2,850	171,000
October	3,080	2,910	175,000

Construction of storage capabilities required for flow regulation will involve a major investment. An estimate of construction and financing costs for proposed storage on the Tualatin, Yamhill, Pudding, South Santiam Rivers, and Rickreall Creek that is based on construction agency cost estimates for proposed sites, and inference from site similarity for sites under study, indicates that an amount in excess of $20 millions will have to be spent if desirable levels of flow are to be maintained.

No construction or financing costs are indicated for the largest block of storage, the 584,000 acre-feet required to meet the problem of Portland harbor. The dams which are depended upon to hold this storage have already been built. Reallocation of functions and costs for specific uses would cause reductions in seasonal power-generating capacities and restriction of reservoir recreation. It is assumed that these losses would be more than offset by the advantages in the form of in-stream recreation, water supply availability, fishery maintenance, and navigational benefits.

In addition to construction costs, $689,000 a year is assigned as the portion of operation and maintenance costs of the Willamette attributable to water quality control. For lack of a better technique, this figure is based on the proportion of total storage used for quality control.

Two desirable provisions could increase the utility of storage for quality control. First, if a fixed amount of storage is available for use as it is needed, flow requirements can be determined by the day-to-day evolution of water quality conditions. The power to spend water as it is needed, rather than depend on a sustained level of flow, would confer both economies in use of stored water, and efficiencies in its application. Secondly, to the extent possible, releases should be made from reservoirs which maintain high water quality during the summer. Augmentation of flows with releases from the North Santiam, Clackamas, McKenzie, or the Middle Fork Willamette benefit water quality more than releases from warmer, west-side tributaries.

OTHER POLLUTION CONTROL PRACTICES

While waste treatment and flow regulation compose the major pollution control needs--as well as the major source of future capital expenditure demands--there are additional methods of controlling pollutional effects which should be diligently pursued.

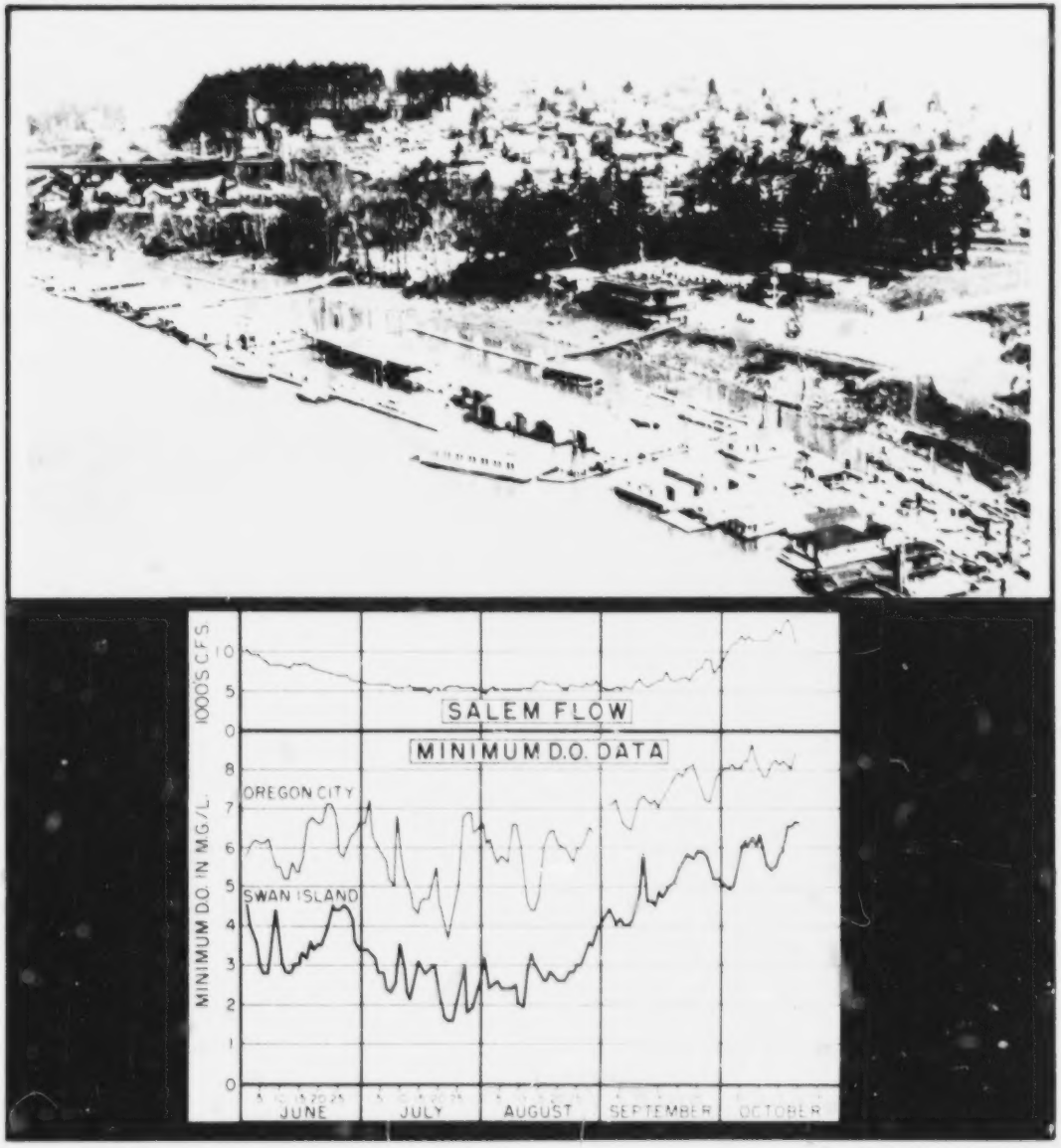
The immediate need in this regard is completion by the city of Portland of its system of trunk sewer interception to eliminate discharges of untreated wastes into Portland harbor. The municipality is actively working to this end; and interception costs compose the major portion of a $14 millions waste control budget adopted in 1965.

Measures supporting water quality, which may readily be adopted in the near future, include the elimination of untreated waste discharges of houseboats and ocean-going commercial vessels to the Portland harbor. The OSSA has statutory authority to prohibit untreated discharges and the FWPCA has initiated a study to determine the extent of such wastes and to devise means of controlling them.

Control of fertilizers and commercial toxicants through the development of optimal application practices and careful

controls is of more than passing importance, in view of the increasing intensity of use of these materials. The U.S. Department of Agriculture, which has the responsibility for regulation of such materials, should make a major effort--ideally through its system of county agents--to insure that use practices which fully reflect the need for protection against all types of environmental pollution are adopted by the individual farmer and commercial applicators. Soil-stabilizing practices, presently effectively promoted for agriculture by the Soil Conservation Service, should be extended to include logging practices, construction, channel improvements, and other activities that bear upon deposition of soil in water bodies. In particular, performance in this regard should be included as a condition of all contracts let by Federal agencies and by contractors engaged in work where Federal grants are involved. The responsibility for such actions is imposed upon Federal agencies by the terms of Executive Order 11288: *Prevention, Control, and Abatement of Water Pollution by Federal Activities*. Institution of similar controls by State and local agencies would be of great value--particularly if statutory authority for inspection and summary powers of abatement were awarded to the OSSA. Controls should be adopted by the State of Oregon against free access of concentrated animal populations--as at feed lots and dairies--to banks of water bodies. Acceleration of the program to control urban runoff by the city of Portland would also be of great value; and economies in attaining the goal could be made by incorporating appropriate design features into the portion of its interceptor sewer system that will be coming under construction in the near future.

The houseboats and pleasure craft moored in the upper Portland harbor represent both pollution sources which are difficult to assess and control, and water users requiring a high level of quality. (OSSA photo)



Emergency measures employed to avert oxygen depletion in Portland harbor during the summer of 1965 provided a demonstration of the efficacy of systematic water quality management. Most of the elements of the suggested pollution control program--water quality monitoring, waste reduction, selective reservoir releases, automated data analysis, inter-agency communication--were utilized to offset the effect of a period of drought on water quality.

In early June, unseasonal low flows resulted in sharp reductions in dissolved oxygen levels in Portland harbor. Deterioration continued characteristically into July, with below average precipitation accelerating the rate of contraction of streamflow and the consequent drain on dissolved oxygen concentrations.

Continuous automatic monitors maintained by the FWPCA at Willamette Falls and at Swan Island in Portland harbor recorded the progressive decline in dissolved oxygen levels. During July, dissolved oxygen concentrations dropped below 2 mg/l for a five-day period. Concerned about effects on fish passage, and lacking a mechanism to deal with the situation, the FWPCA arranged a meeting with the OSSA and State and Federal fishery agencies.

The conferees agreed that the situation imposed a threat to the fall run of salmon, and initiated measures to raise the level of dissolved oxygen. The Bonneville Power Administration and the U. S. Army Corps of Engineers, the two Federal agencies regulating streamflow in the Willamette River, were brought into subsequent meetings. It was hoped that the operation of power and flood control facilities could be adjusted to permit reservoir releases ahead of the usual regulation schedule, although storage for water quality control is not authorized in any of the existing reservoirs.

At the instance of the inter-agency group, the Portland General Electric Company provided an emergency release of 400 cfs from its Clackamas River reservoirs during the period August 12 to 15. The cool, high quality water (rapidly available in Portland harbor because of the nearness and time of travel of the Clackamas) produced an immediate rise in dissolved oxygen concentrations.

The effect of this relief was partially offset by a continuing decline in main stem flows. On August 14, however, the Publishers Paper Company pulp and paper mill at Newberg was temporarily shut down, providing a major reduction in waste loads. The dissolved oxygen level stabilized, and began thereafter to rise.

Comparison of results of the Willamette River oxygen-sag computer program with daily flow gaging records indicated the need of another 500 cfs of streamflow. After inter-agency discussion of the circumstances, the Division Engineer, U. S. Army Corps of Engineers, authorized operation of Willamette Basin Reservoirs in a manner to maintain streamflows at Salem up to 6,000 cfs. Corps of Engineers reservoirs in the upper basin began, on August 20, to release 500 cfs of supplemental flows. Such releases continued until mid-September, when power releases normally scheduled for that time increased flows beyond the required minimum.

While outstanding cooperation was attained by arrangements at administrative levels, it was generally recognized that such pollution control measures were approved only on an interim emergency basis; and that the releases of water for quality control would not constitute a precedent for similar action in future years. Had additional flow regulation been required at the expense of storage for power generation, the cost would have been borne by pulp and paper plants, which on August 16 agreed to reimburse such costs, or to further curtail production if indicated emergency measures were inadequate.

The situation showed the value of a water quality management regimen that includes quality monitoring and provision of streamflow regulation as it is needed. It also demonstrated the need for establishment of permanent lines of communication and established procedural relationships between water management agencies. What was arranged by negotiation in an emergency situation should, in the future, be crystallized into a routine pattern of management. The necessary preconditions are authorization of storage for water quality control, and the presence of adequate waste treatment to empower the use of such storage.

MANAGEMENT PRACTICES

A precondition for effective management is expansion by the State of Oregon of its existing quality standards for the Willamette River and its tributaries. Such standards, while defining the principle uses of the river system--fish production, water supply, and recreation--should also be sufficiently detailed to allow for exceptional circumstance, and to provide goals for management and yardsticks for management effectiveness.

The elements that would enter ideally into a water quality management system would be those that make it possible to make effective day-to-day decisions affecting flow and waste discharges. Given sufficient information about the river system, and given a measure of power to control flows and wastes, such an ideal system is theoretically possible. At the present time, there are two major obstacles to putting these procedures into operation.

A clouded water rights picture makes it impossible for realistic base flows to be established for quality regulation. Should storage for flow regulation be authorized in Federal reservoirs, there is no guarantee that the flows would serve their function, due to the possibility of withdrawal for irrigation or other use. The OSWRB is statutorily empowered to establish flows required for quality control. An early step in outlining a program to implement water quality planning should be the establishment by the OSWRB of base streamflows for all water bodies in the Willamette Basin in order that necessary flows--including those from Federal storage projects--are allowed to pass through the length of stream in which they are required. Such base flows would then serve for establishment of permissible waste loading levels. Adjudication of water rights must be accomplished, if firm rights for quality control are to be established. Based on the cost of adjudicating claims in the Tualatin and Mill Creek Basins, the Office of the State Engineer has estimated that an investment of about $1 million will be required to establish a reasonable system of priorities for water rights in the Willamette River Basin.

A second obstacle to effectuating a realistic implementation program lies in the OSSA's weak legal position in establishing desired waste discharge levels. The OSSA must operate largely through persuasion and education, depending on the prolonged and uncertain process of civil suit to press its decisions in the event of violations. Since proof of damage by a single source is difficult to establish in a water body that is subject to a variety of influences, the OSSA has been reluctant to engage in judicial disputes with even the most flagrant and

Oregon capitol, Salem.

persistent violators of its instructions. Given summary abatement powers by legislative enactment, the Sanitary Authority would be in the much stronger position of contesting its case in a criminal court, with clearly demonstrable evidence of discharges exceeding established limits. It is presumed that recourse to the larger area of judicial process should supply sufficient surety that the individual community or industry would not be subject to arbitrary or capricious orders by the Sanitary Authority.

A third--less pressing--area in which decision-making should be made more effective, by development--as authorized by Executive Order 11288--of clearly defined working arrangements, lies in the realm of relationships among Federal agencies. Programs of agencies engaged in water resource management, or in land management having an effect on water quality, should be reviewed annually by the FWPCA; which, then, would be in a position to evaluate effectiveness of pollution control procedures, and to advise indicated improvements. The U.S. Army Corps of Engineers, the Bureau of Reclamation, the Forest Service, the Bureau of Land Management, the Soil Conservation Service, the Bonneville Power Administration, the Bureau of Public Roads, and the Fish and Wildlife Service are among the agencies which have an immediate interest in water quality and which should meet on a normal basis with the FWPCA. An extension of this type of cooperative relationship will become necessary if flow regulation for water quality control is authorized in Federal storage projects in the basin. By negotiation and discussion with the project managing agency, the FWPCA would be in a position to establish, in a fashion that recognized competing uses of stored water, its fund of storage for the coming year. An optimum allocation which did not unduly conflict with other uses of the water might be made by arrangement for disposition of that fund, according to the situation of the particular year.

JULY 1965
POLLUTION CONTROL PRACTICES TO BE INITIATED IN NEAR FUTURE

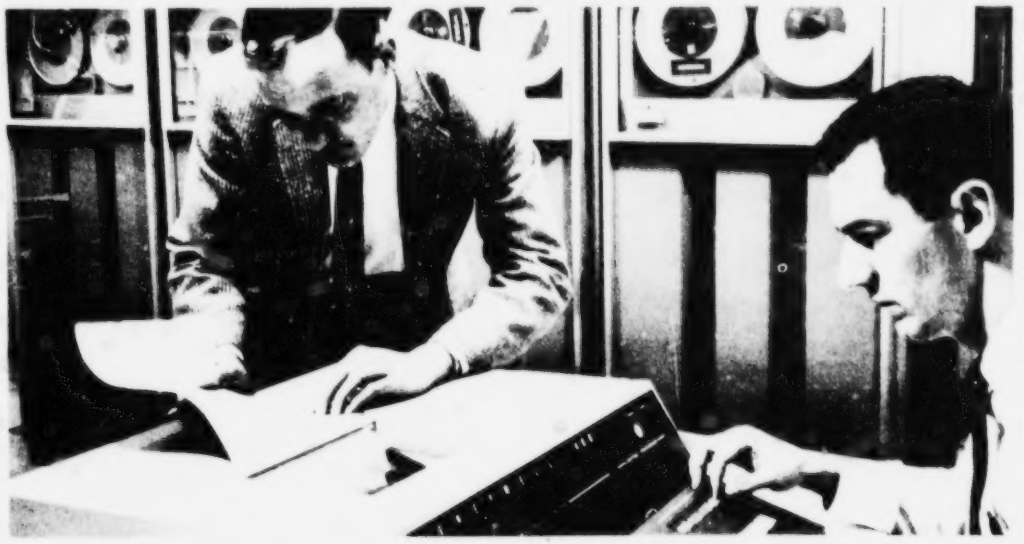
Category	Requirement	Location	Responsibility	Estimated Investment	Annual Cost Estimate
Waste Treatment	Secondary Recovery	Lebanon Salem	Crown Zellerbach Boise Cascade	$2,000,000	$ 35,000
	Enlargement Enlargement Enlargement Enlargement Enlargement	Dallas Fanno Cr. S.D. Mt. Angel McMinnville Sweet Home	Municipality Sanitary District Municipality Municipality Municipality	2,900,000	90,000
Flow Regulation	35 cfs (7800 A.F. of storage)	Yamhill	U.S.-Red Prairie Project	2,700,000	9,000
Other Pollution Control Practices	Elimination of navigation and houseboat wastes	Portland harbor	OSSA-U.S. Coast Guard	Not available	
	Soil stabilizing practices	Basin-wide	All land use and management interests	Not available	
	Control of commercial toxicants	Basin-wide	U.S. Dept. Ag. Ore. Bd. Health	Not available	
	Control of storm water overflow	Portland	OSSA-Municipality	Not available	
Management Practices	Research-handling of wastes not amenable to collection	Basin-wide	FWPCA	Not available	
	Program development-Basin-wide waste collection and treatment	Tualatin Basin	Municipalities, Industries, OSSA, FWPCA	Not available	
	Telemetering of monitored data	Four automatic monitors	FWPCA	40,000	1,000

Essential to the operation of a management program is the availability of adequate and readily accessible information. Knowledge of the operation of the Willamette River system is far more complete than for other Pacific Northwest water bodies; but additional information needs exist. The OSSA presently maintains a system of periodic water quality monitoring for the Willamette River and operates an automatic monitor at Newberg. The FWPCA operates three automatic monitoring stations and a water pollution surveillance system station in the lower basin. These complementary systems should be expanded. Inauguration of periodic sampling of tributaries would add materially to knowledge of the water quality of the river system. In particular, FWPCA water pollution surveillance system stations

should be established to record the water quality in any tributary where storage is provided from Federal reservoirs for flow regulation for quality control. In addition, a water pollution surveillance system station at Corvallis would provide a means of measuring the progression of quality, and calibrating mathematical models of the river system to reflect accurately the effects of downstream waste loads. With existing forecasting techniques, the combination of the four existing monitors--telemetered to a central computer system--would allow for release of available stored water for curtailment of production by manufacturing plants in the absence of storage for flow regulation) which would avert critical water quality depressions.

To complement the suggested system of water quality monitoring, improvements in flow-gaging practices and in knowledge of waste discharges are essential. The existing system of gages for the Willamette system meets all requirements for extent of flow information. Reporting, however, is delayed; and flow information is not available in time to meet management needs. Instrumentation to provide regular daily flow reports during the critical season for two points on the Tualatin River, the Clackamas River, Portland harbor, and on other streams for which flow regulation storage has been proposed, would require an investment of about $0,000 and impose a $2,000 annual cost for operation and maintenance.

Dependable data regarding waste strengths and treatment effectiveness must also be obtained, if an equitable and responsive management program is to come into being. Limited reporting of waste discharges is presently available



LONG TERM POLLUTION CONTROL NEEDS SUMMARIZED

Category	Requirement	Location	Responsibility	Estimated Investment	Annual Cost Estimate
Waste treatment	Secondary treatment & provision for expansion	All pulp & paper mills	Pulp & paper mills	$19,000,000	$1,900,000
	Expansion & replacement of plant	All communities	Municipalities & industries	46,100,000	1,900,000
	Advanced treatment	Tualatin Basin	Municipalities & industries	8,600,000	350,000
Flow Regulation	55 cfs (6360 A.F. of storage)	Pudding River	U.S.-site uncertain	13,880,000	50,000
	200 cfs (35,880 A.F. of storage)	Tualatin River	U.S.-site uncertain		
	13 cfs (3120 A.F. of storage)	Rickreall Creek	U.S.-Dallas-Monmouth Project		
Other Pollution Control Practices	Control of storm water overflow	All municipalities	Municipalities	Not available	
Management Practices	Day-to-day control of flows	Basin-wide	All relevant agencies FWPCA	36,000	10,000
	Monitoring of tributaries	All streams with established base flow			

to the OSSA. This should be supplemented to include daily reports from all major waste sources during critical periods, and annual in-plant surveys by the OSSA, both to provide a check of reporting efficiency and to indicate areas in which waste control improvements might be made.

Another area of management practice which has the potential for providing direct and significant efficiency increments, consists in methodical up-grading of skills of waste treatment plant operators. The short courses presently conducted by Oregon State University and the OSSA should continue to be held; and attendance should be encouraged. Perhaps the most direct method of increasing operator skill would be amendment of admittedly deficient pay scales to attract qualified persons, reward achievement, and encourage professionalism.

Research and program development should be integral parts of the management plan. The most obvious immediate research need is found in the problems posed by wastes that are not amenable to collection and treatment--including the wastes of navigation, land use, and urban runoff. Program development essentials include: 1) modification and updating of this comprehensive plan to include deficiencies, remedy errors, provide for unforeseen events; and 2) closely related to research requirements, the imminent necessity to develop a basin-wide program of pollution abatement and water quality maintenance for the Tualatin River Basin. Creation of a unified policy for pollution control in an area marked by a plethora of independent jurisdictions, problems of municipal and industrial wastes, intensive agriculture, and urban runoff, would be of more than local utility. Federal grants are available to aid in the development of such a program.

Financing the proposed management scheme would prove far less demanding than the other elements of the water pollution control plan. An initial investment of $1.1 million would be required to adjudicate water rights and provide necessary monitoring equipment. Annual costs--gaged at the rate of $10,000 per man year--would represent less than a hundred thousand dollars per year, most of it in the form of additional personnel for the OSSA.

ALTERNATIVES

The program for pollution abatement and water quality maintenance presented in this report is considered to represent an optimum solution to the water quality problems of the Willamette River. It is not, however, considered to be either a final or a maximum solution. Other pollution control possibilities are available--and more should become evident as technology and knowledge of the river system advance.

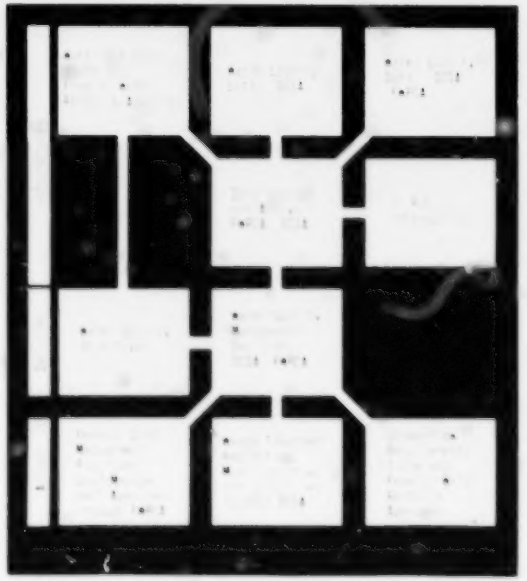
The most obvious alternative is to simply allow water quality to deteriorate, with only enough waste treatment provided to avert nuisance.

More acceptable alternatives that deserve exploration, although they do not presently appear to fit into the optimal solution proposed in this report, include reaeration of the lower Willamette and transmission of wastes out of the Tualatin River Basin.

The significance of reaeration is obvious in any situation which is characterized by DO concentrations that are less than those demanded by uses. By reaerating the water body, it is possible to maintain a suitable DO level under circumstances where the process of waste assimilation is continuing and would, otherwise, result in oxygen depletion. Unlike flow augmentation and waste treatment, reaeration is specific in its operation. Its benefits extend only to dissolved oxygen, where the more general operations of waste treatment and flow regulation provide improvements in several water quality parameters.

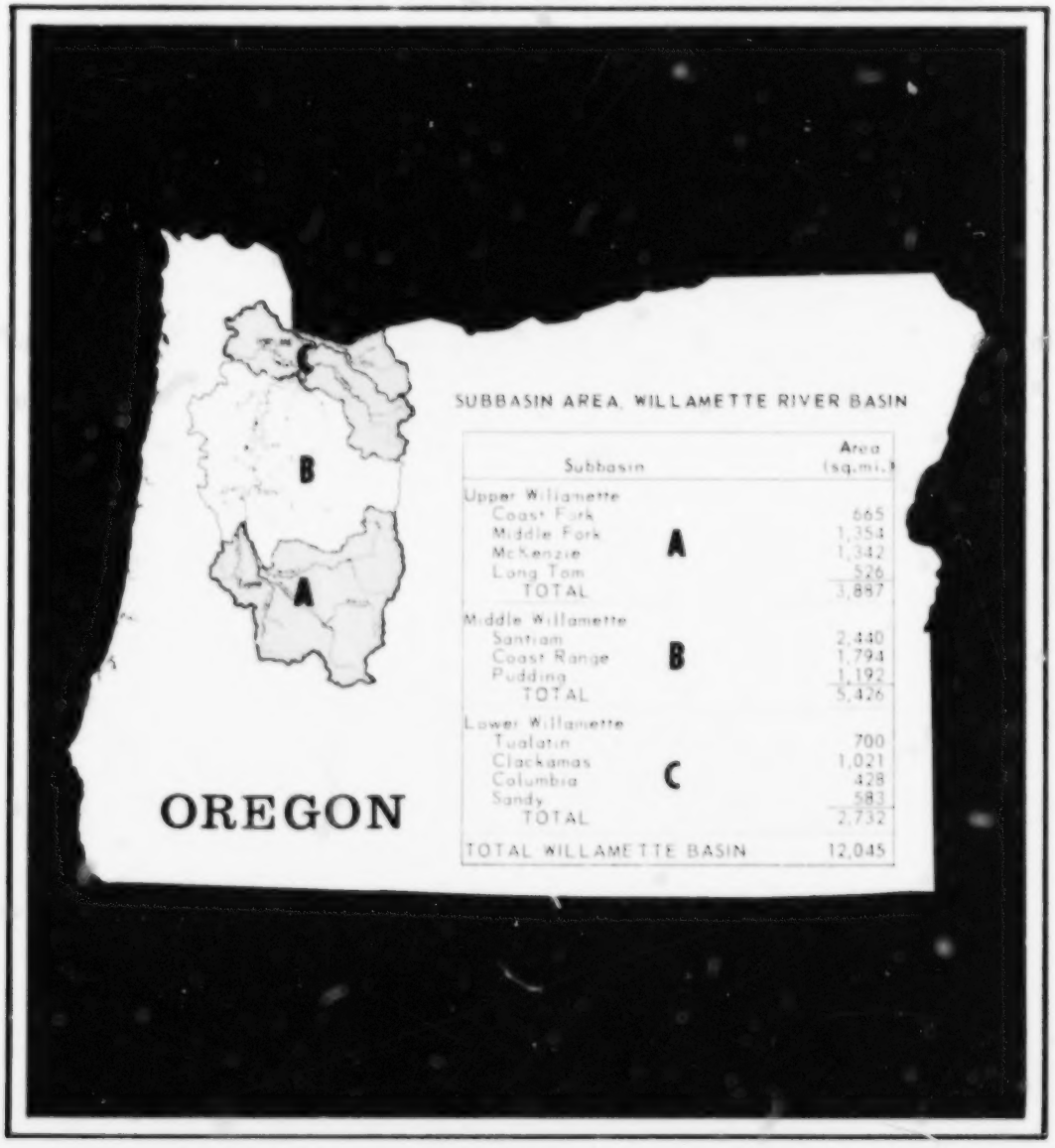
There are at least two ways to accomplish effective reoxygenation of the lower Willamette River by inducing reaeration. The simplest method is to allow the stream to pass over Willamette Falls throughout the summer. The turbulence and atmospheric contact that occurs at the falls provide substantial aeration before the Willamette, whose oxygen supply is partially depleted at that point by upstream waste loads, enters Portland harbor. During low flows, however, the entire river is channeled through a generating plant which serves the two pulp and paper mills situated at the falls. If diversion through the turbines were to be interrupted during the critical season, the desired dissolved oxygen concentration of 5 mg/l would, theoretically, be maintained through the harbor. The cost to the pulp and paper mills--assuming that purchases or power for 120 days were twice as expensive as captive generation of power--would be about $95,000 a year.

Reaeration may also be accomplished by installation of mechanical devices to induce turbulence and force oxygen into solution with the water. Calculations indicate that in the absence of flow reg-



CHAPTER TWO

THE STUDY AREA



SUBBASIN AREA, WILLAMETTE RIVER BASIN

	Subbasin	Area (sq.mi.)
Upper Willamette		
	Coast Fork	665
	Middle Fork	1,354
A	McKenzie	1,342
	Long Tom	526
	TOTAL	3,887
Middle Willamette		
	Santiam	2,440
B	Coast Range	1,794
	Pudding	1,192
	TOTAL	5,426
Lower Willamette		
	Tualatin	700
	Clackamas	1,021
C	Columbia	428
	Sandy	583
	TOTAL	2,732
TOTAL WILLAMETTE BASIN		12,045

The Willamette Basin's 12,000 square miles comprise one-eighth of the total Oregon land area, yet it is the home of the State's population resident in the basin.

Physical Description

The Willamette River Basin is a rectangular drainage trough 150 miles long and about 75 miles wide, lying between the Cascade and Coast mountain ranges in northwestern Oregon. The Calapooia Mountains form the southern boundary of the basin. The runoff from its 12,045 square miles flows northward to the Columbia River, the northern perimeter of study area.

The main stem Willamette River is formed near the city of Eugene by the junction of its Coast Fork and Middle Fork; within a few miles, it receives its largest tributary, the McKenzie River. As it flows north through a valley floor that slopes from about 500 feet to 30 feet above sea level at the river's mouth, the Willamette is joined by a number of tributary streams. From the Coast Range to the west, the Long Tom, Marys, Yamhill, and Tualatin Rivers are the principal contributors to flow. The major Cascade-originating tributaries, the McKenzie, Santiam, and Clackamas, are all larger, swifter streams than the west-bank tributaries.

The Willamette River's water yield of about 26 million acre-feet annually is about one-seventh that of the entire Columbia River system; its discharge exceeds that of any other western basin except the Columbia and Snake Basins.

LAND USE AND OWNERSHIP

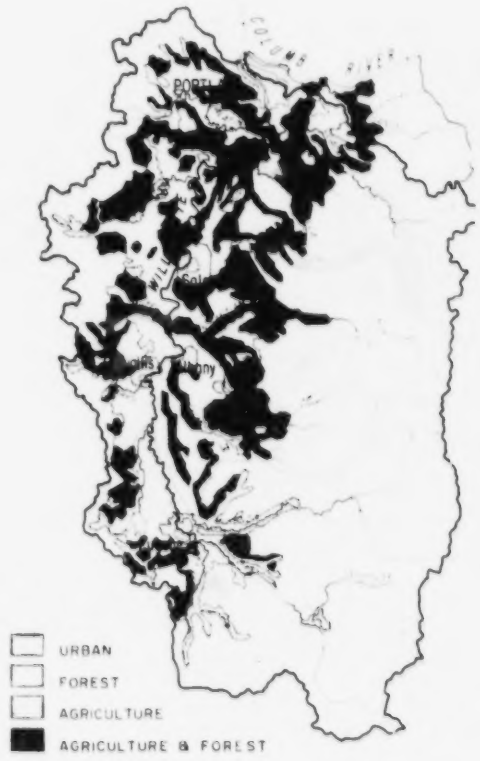
Of the basin's 7.7 million acres, about 60 percent is forested, 19 percent is in cropland (of which about 191,000 acres is irrigated); 3 percent is rangeland, 1 percent is water surface, and 11 percent is in other uses. Land ownership of the basin is 37.8 percent Federal, 2.7 percent State and local, and 59.5 percent private.

CLIMATE

The proximity of the Willamette Basin to the Pacific Ocean, generally westerly winds, and varied topography combine to give the basin a temperate marine climate characterized by wet winters and dry summers. Occasionally, maritime control gives way to continental influences for short periods, particularly in midsummer and mid-winter, resulting in east winds and relatively extreme temperatures.

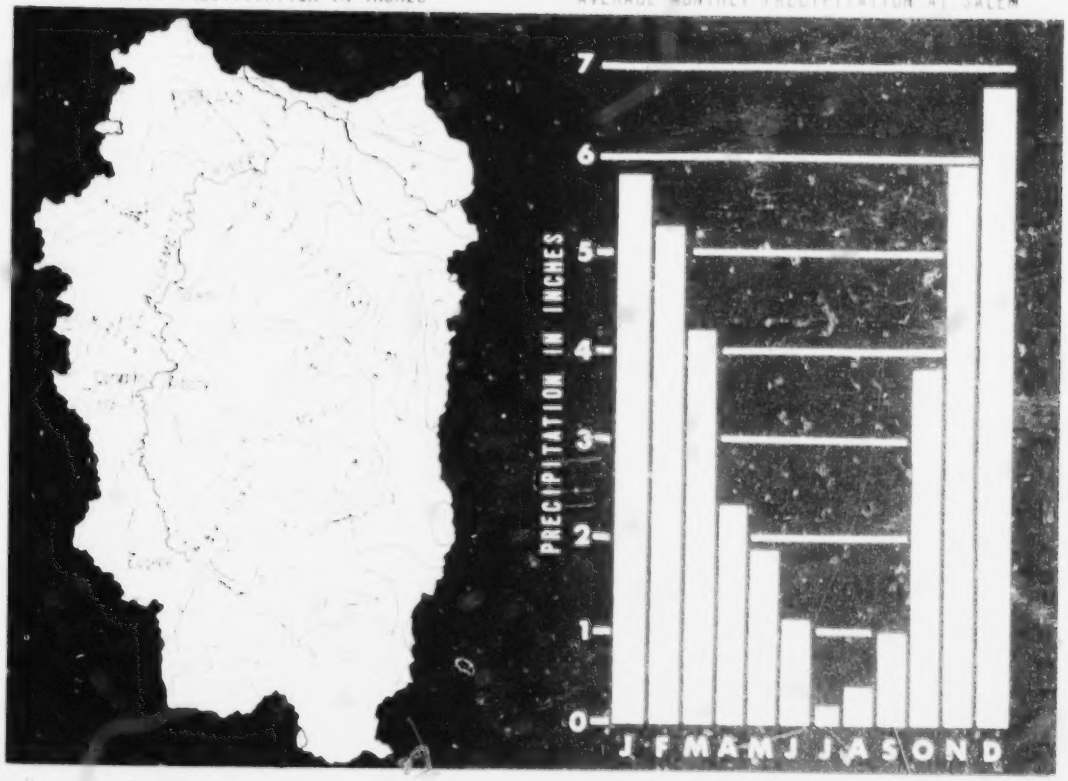
Relative humidity undergoes large diurnal changes in summer but remains relatively constant in winter. Average values in July at Salem are 87 percent and 40 percent at 4:00 a.m. and 4:00 p.m., respectively. Corresponding values for January are 88 percent and 79 percent. Occasionally, the relative humidity will drop as low as 19 to 29 percent during the warmest part of the day.

Temperatures in the Willamette Valley average 38 degrees (F) in January and 66 degrees in July. Most stations have not had a maximum temperature greater than 98 degrees or a minimum temperature lower than 16 degrees for over half the years of record. Temperatures of 90 degrees or more occur only about six to eight days a year, and those below zero occur on an average of about once in 25 years. Extremes of temperature recorded at Salem are 108 and minus 10 degrees.



Land Area Ownership	Total Basin		Upper Basin		Middle Basin		Lower Basin	
	Acres	% Basin	Acres	% Basin	Acres	% Basin	Acres	% Basin
Federal								
Forest Service	2,449,100	31.8	1,301,400	16.9	471,000	6.1	676,700	8.8
BLM	415,700	5.4	163,600	2.1	214,100	2.8	38,000	0.5
Corps of Eng.	48,300	0.6	35,000	0.4	13,300	0.2	–	–
State	162,600	2.1	7,600	0.1	114,700	1.5	40,300	0.5
County and City	48,800	0.6	8,200	0.1	24,600	0.3	16,000	0.2
Private	4,584,700	59.5	971,900	12.6	2,635,000	34.2	977,800	12.7
TOTAL	7,709,200	100.0	2,487,700	32.2	3,472,700	45.1	1,748,800	22.7
Forest	5,093,858	66.1	1,775,368	23.0	2,121,240	27.6	1,197,250	15.5
(Grazed)	(467,732)	(6.1)	(129,432)	(1.7)	(285,450)	(3.7)	(52,580)	(0.7)
Cropland	1,456,114	18.9	154,794	2.0	1,033,350	13.4	268,000	3.5
(Irrigated)	(193,650)	(2.5)	(30,330)	(0.3)	(128,510)	(1.7)	(34,810)	(0.5)
Rangeland	236,940	3.1	47,640	0.6	134,000	1.8	55,300	0.7
Water Surface	72,400	0.9	37,400	0.5	5,900	<0.1	29,100	0.4
Other	849,902	11.0	472,542	6.1	178,210	2.3	199,150	2.6
TOTAL	7,709,244	100.0	2,487,744	32.2	3,472,700	45.1	1,748,800	22.7

ANNUAL PRECIPITATION IN INCHES



AVERAGE MONTHLY PRECIPITATION AT SALEM

PRECIPITATION

Economic & Population Base

This section, including analysis of present economic base and projected future growth, is a summary of three unpublished, detailed economic reconnaissance studies of the Willamette Basin. These analyses have included available data and projections from a number of detailed studies concerning specific aspects of the basin's economy. In particular, the resource studies by Bonneville Power Administration, the planning studies of the Oregon Bureau of Municipal Research, and the population and economic base studies of the Portland Metropolitan Planning Commission have been used in the base analyses.

For economic study purposes, the Willamette Basin has been divided into three subareas — the Upper Willamette (Lane County), the Middle Willamette (Benton, Linn, Marion, Polk, and Yamhill Counties), and the Lower Willamette (Clackamas, Multnomah, and Washington Counties). Economic data relating to waste production and water supply were distributed into service areas and river subbasins.

CHANGE IN WILLAMETTE BASIN POPULATION IN PERIOD 1960-1964

SUBAREA	1960 CENSUS	1964 ESTIMATE	% CHANGE FROM 1960
Upper	156,000	190,000	16.7
Middle	288,000	319,000	10.8
Lower	714,000	780,000	9.2
TOTAL	1,158,000	1,289,000	10.2

The method of analysis involved, first, an examination of the natural resource base (primarily forests and agricultural land). The potential for employment in basic industries was considered in relation to market demand trends indicated by regional and national population projections. Employment, other than basic employment, was projected as both a function of state population and on the basis of past trends in the ratio between service employment and basic employment.

The method of projecting future population by estimating future job opportunities was correlated with another approach, the ratio method, whereby an assumed future national population was allocated, first, to Oregon and, then, to the Willamette Basin portion of Oregon. Allocations were based on trends in these ratios during recent decades, modified by judgment according to broad resource considerations. The two approaches were reconciled to yield a single projection of future growth.

PRESENT POPULATION AND ECONOMIC BASE

The Willamette Valley is relatively densely populated by national standards. Population per square mile was about 93 in 1960, which is above the national average of 60 for the conterminous United States. In the lower Willamette Valley, the density is about 260 per square mile; the population density in the remainder of the valley floor is also high. The concentration of urban-industrial centers along the river is expected to continue into the future. Thus, water supply, sanitation, and waste disposal problems will become increasingly interrelated.

The population of the Willamette Basin in 1960 was about 1.2 million people. A 1964 estimate of population indicates that the basin's population had grown to nearly 1.3 million. Population data are analyzed in terms of major service areas and subbasins. (A service area represents a contiguous group of communities that could likely be served by a common water supply or waste treatment facilities.) These units have been used in the assessment of present and future water supply and waste production in succeeding sections of this report.

The Willamette Basin contains four major service areas--Portland, Salem, Albany-Corvallis, and Eugene-Springfield. Together, they represent 80 percent of the total population and about 95 percent of the population of urban and incorporated areas. Other service areas considered are: Cottage Grove, Oakridge, Newberg, McMinnville, Silverton, and Woodburn.

Resource base and employment analysis reveals distinct differences in the economies of the Upper, Middle, and Lower Willamette subareas. The Upper Willamette is heavily dependent on lumber and wood products industries, which accounted for 80 percent of all manufacturing employment in 1960. The University of Oregon is also an important factor in the Upper Willamette's economy.

The economy of the Middle Willamette is more diversified than the Upper Willamette, but lumber and wood products are also important here, constituting some 55 percent of all manufacturing employment in 1960. Other important specializations in the middle subarea are agriculture, food processing, and pulp and paper manufacturing. Service employment is relatively high due to educational institutions at Corvallis, Monmouth and Salem, and the State capital at Salem.

The Lower Willamette subarea includes Portland--the metropolitan center not only for the Willamette Valley but for all of Oregon and part of Washington. Portland is a leading northwestern port and a center of commerce, transportation and distribution. Diversified manufacturing and service industries characteristic of a regional center are the primary factors in the Lower Willamette's economy. This area also has relatively high employment in pulp and paper manufacturing due to the plants at West Linn and Oregon City.

Certain industries have been examined in detail because of their over-all size and significance to water supply and water pollution control considerations, both now and in the future. These industries are pulp and paper, wood products, and food processing. In 1960 employment in these three types of manufacturing made up a large share of total manufacturing employment.

PROJECTED ECONOMIC BASE

As used in this report, the term "projection" is not meant to denote desirable goals; rather the projections are calculated assumptions of growth and subsequent water demand that are likely to occur at about the times given. Such calculations are a necessary step in resource planning and development, due to long lead times for measures to enhance water quality and prevent its degradation.

Pulp and paper. Available timber resources in the Upper Willamette Basin are expected to increase during 1960-1985 due to a slightly higher allowable cut on National Forest lands and intensified forest management. Expansion of pulp capacity at Springfield from 400 to 1,150 tons per day was accomplished by Weyerhaeuser Company in 1965. Additional resources available for making pulp suggest a further expansion to 1,600 tons

Employment distribution reflects a high degree of development of industries characterized by large organic waste loads, such as forest products--including pulp and paper--and food processing.

EMPLOYMENT, BY MAJOR INDUSTRY, APRIL 1960

Industry	Employment in Thousands: Upper Willam. Sub-Area *a*	Middle Willam. Sub-Area *b*	Lower Willam. Sub-Area *c*	Total Willam. Sub-Area
GOODS, Total	19.4	31.1	67.5	118.0
Agriculture, forestry, fish., mining	2.6	10.9	9.8	23.3
Manufacturing, Total	16.8	20.2	57.7	94.7
Lumber, wood prod., furn	13.5	11.0	9.6	34.1
Food and kindred	1.2	3.0	8.3	12.5
Pulp, paper and allied	.3	1.4	3.8	5.5
All other manufacturing	1.8	4.8	36.0	42.6
CONSTRUCTION	4.0	6.3	17.2	27.5
MILITARY	.1	.6	1.5	2.2
SERVICES *d*	34.1	56.6	192.7	283.4
TOTAL EMPLOYED	57.6	94.6	278.9	431.1
UNEMPLOYED	3.7	6.8	14.8	25.3
TOTAL LABOR FORCE	61.3	101.4	293.7	456.4

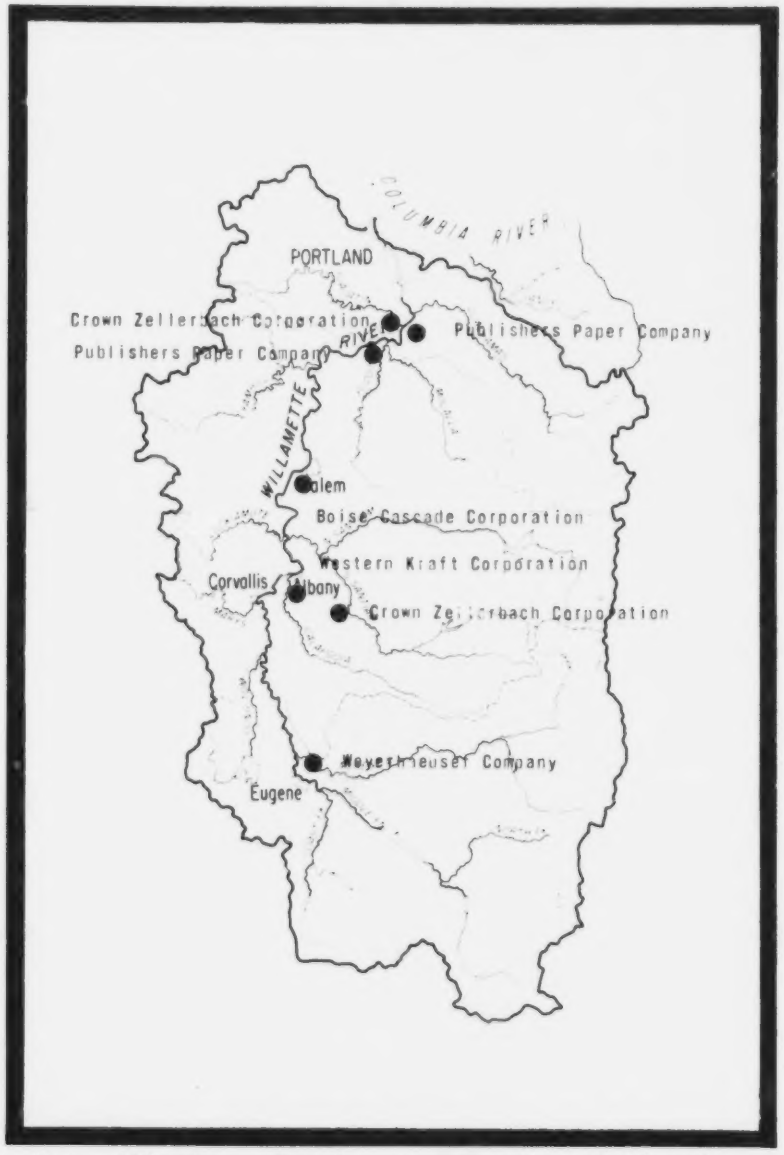
a - Equivalent to Lane County
b - Includes Benton, Linn, Marion, Polk and Yamhill Counties
c - Includes Clackamas, Multnomah and Washington Counties.
d - Includes "Industry not Reported" category.
Source: U.S. Census of Population, 1960.

PROJECTED CAPACITY, PULP, PAPER AND COMPOSITION BOARD

BASIN AND CITY	1960	1965	1985	2010
Lower Willamette:				
West Linn-Oregon City area	1005	1050	1160	1260
Forest Grove[1]	70	70	70	70
Molalla[1]	-	-	70	100
Estacada[1]	-	-	-	70
TOTAL	1075	1120	1300	1500
Middle Willamette:				
Lebanon	80	100	100	100
Corvallis[1]	30	-	100	100
Salem	150	210	300	500
Newberg	150	380	450	500
Albany	240	500	600	800
TOTAL	650	1190	1550	2000
Upper Willamette:				
Eugene-Springfield area	400	1150	1600	2000
Oakridge[1]	-	-	200	300
TOTAL	400	1150	1800	2300

[1] Composition board

PULP AND PAPER MILL LOCATIONS



Pulp and paper production is the major source of wastes in the Willamette Basin. Although raw material supplies are fully utilized at this time, moderate growth of output is expected to continue throughout the study period.

per day by 1985 and 2,000 tons per day by 2010.

Large increases in pulp and paper output are not expected in the lower subarea, due to limitations on the availability of raw material. Physical limitations of the plant sites at West Linn and Oregon City and competition for raw materials with plants at St. Helens, Camas, Newberg, and Salem further limit expansion.

Food processing. Agricultural production and the physical output of food processing plants in the upper basin are expected to double from 1960 to 1985 and double again from 1985 to 2010. Food processing activities in the Upper Willamette area are projected to be concentrated in the Eugene-Springfield urban area or along the main stem Willamette River below Eugene.

Increased agricultural production, resulting from more irrigation and higher productivity per acre, will make possible a substantial increase in food processing in the Middle Willamette area. Output from food processing plants is expected to double by 1985 and double again by 2010. Most of the increased production is expected to occur in the Salem urban area but with added output also at Albany, Silverton, and Woodburn.

Substantial increases in food processing are expected to occur in the Lower Willamette, where growth will be similar to the other parts of the basin.

Services. Services are a major portion of the economy for the entire Willamette Basin. In the future, it is expected that the ratio of service industries to basic industries will continue to increase, resulting in a relatively greater proportion of service industry employment to total employment.

In the Upper Willamette, the University of Oregon will contribute to the growth of that region. In the Middle Basin, the institutions of higher learning and the State capital will also contribute to increased employment. In the Lower Willamette, service employment in the city of Portland will continue to increase with the population. These services include truck transportation, warehousing, wholesale trade, finance-insurance-real estate, professional services, education, and administration.

Based on these major growth factors and relationships, a projection of 1985 and 2010 employment and resultant population has been developed. This projection indicates that the 1960 employment of the Willamette Basin will double by 1985 and nearly triple by 2010.

Forest products industries dominate the economy of the Willamette Basin. [illegible] percent of all manufacturing employment is provided by [illegible] trees.

EMPLOYMENT, BY MAJOR INDUSTRY, AND POPULATION, WILLAMETTE ECONOMIC STUDY AREA AND SUB-AREAS
Employment and Population in Thousands
(1960 Actual; 1985 and 2010 Projected)
TABLE IV-6

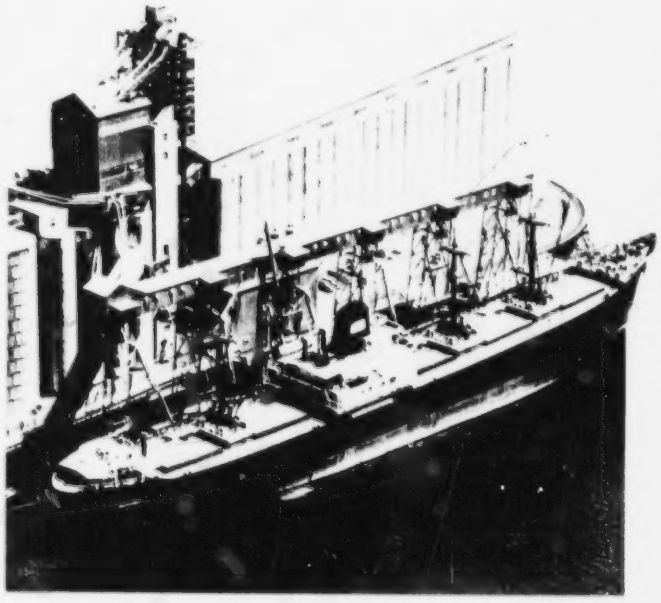
Industry Group	Upper Sub-Area [a]			Middle Sub-Area [b]			Lower Sub-Area [c]			Total Willamette Econ. Study Area		
	1960	1985	2010	1960	1985	2010	1960	1985	2010	1960	1985	2010
Agric., forestry, fish., mining	2.6	2	2	10.9	12	14	9.8	10	10	23.3	24	26
Manufacturing, Total	16.8	23	34	20.2	36	63	57.7	112	200	94.7	171	297
Lbr., wood prod., furn., and fixtures	13.5	16	18	11.0	12	13	9.6	12	14	34.1	40	45
Food & Kind. prod.	1.2	2	3	3.0	6	12	8.3	13	19	12.5	21	34
Pulp and paper [d]	.3	2	3	1.4	2	4	3.8	4	5	5.5	8	12
All other manufacturing	1.8	3	10	4.8	16	34	36.0	83	162	42.6	102	206
Services and Const. [e]	38.1	65	118	60.8	134	262	209.9	403	735	308.8	602	1115
Total Employment [f]	57.5	90	154	91.9	182	339	277.4	525	945	426.8	797	1438
Population [g]	163	250	430	278	530	980	728	1380	2460	1169	2160	3870
Multiple, Pop'n x Employment [h]	2.8	2.8	2.8	3.0	2.9	2.9	2.6	2.6	2.6	2.7	2.7	2.7

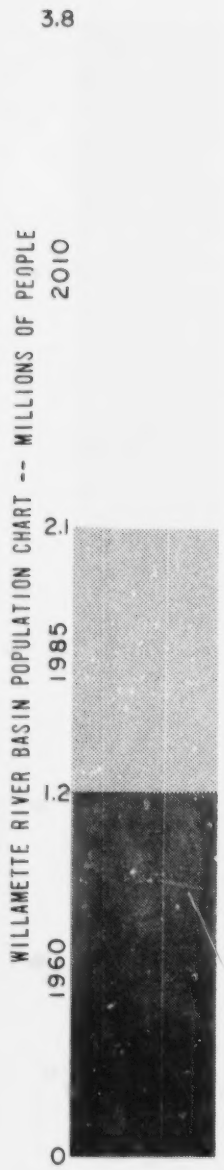
a - Includes all of Lane County.
b - Includes all of Benton, Linn, Marion, Polk and Yamhill Counties.
c - Includes all of Clackamas, Multnomah and Washington Counties.
d - Includes not only pulp and paper manufacturing, but also fabricated paper products, such as boxes and envelopes.
e - Includes "Industry not Reported" category.
f - Employed civilian labor force.
g - Future population estimated by allocating to the various sub-areas of Oregon the projected State population. (See page V-10) More broadly, the population estimates here are also based on the multiple of the labor force, as shown in this table.
h - 1960 actual; 1985 and 2010 derived from estimated future population.

[illegible]

FUTURE POPULATION

The total Willamette population is projected to more than triple by 2010, growing from 1.2 million to 3.8 million. The majority of the growth will occur in the four major service areas, these four areas (Eugene-Springfield, Albany-Corvallis, Salem, and Portland) are forecast to contain about 87 percent of the total Willamette Basin population by 2010. The Portland service area alone will contain 60 percent of the total basin population by the end of the study period.





POPULATION, WILLAMETTE BASIN AND TRIBUTARY BASINS, 1960, 1985, 2010

Area	Population in thousands 1960	1985	2010
Upper Willamette Basin - TOTAL	156	237	407
Eugene-Springfield Service Area 1/	103	173	312
Main Stem Willamette Basin	10	11	12
Long Tom Basin	11	12	16
Coast Fork Basin			
Cottage Grove Service Area	5	8	17
Other	10	11	14
McKenzie Basin	6	8	12
Middle Fork Basin			
Oakridge Service Area	3	5	11
Other	8	9	13
Middle Willamette Basin - TOTAL	288	553	1024
Albany-Corvallis Service Area 2/	52	130	276
Salem Service Area 3/	90	206	416
Main Stem Willamette			
Newberg Service Area	6	17	38
Other	32	53	90
Mary's Basin	4	5	6
Luckiamute Basin	5	6	8
Yamhill Basin			
McMinnville Service Area	9	12	18
Other	17	20	25
Calapooia Basin	8	11	14
Santiam Basin	26	31	38
Pudding Basin			
Silverton Service Area	5	10	16
Woodburn Service Area	5	11	18
Other	19	22	27
Molalla Basin	10	19	34
Lower Willamette Basin - TOTAL	714	1351	2408
Portland Service Area 4/	675	1291	2321
Main Stem Willamette Basin	4	7	13
Tualatin Basin	18	26	35
Sandy Basin	3	6	10
Clackamas Basin	14	21	29
UPPER, MIDDLE & LOWER BASIN TOTAL	1158	2141	3839
NINE-COUNTY ECONOMIC STUDY AREA 5/	1169	2160	3870

1/-Includes Eugene, Springfield Urban area, Coburg, Junction City, and the Elmira-Venita Community.
2/-Includes Albany Urban Area, Corvallis Urban Area, Sodaville, Lebanon, Sweet Home, Waterloo and Philomath.
3/-Includes Salem Urban Area, Dallas, Independence, Monmouth and Turner.
4/-Includes Boring, Cornelius, Forest Grove, Hillsboro, Sherwood, Sandy, and Portland Urban Area. The Portland Urban Area is defined as: Multnomah County (excluding Sandy Basin) including Portland, Fairview, Gresham, and Wood Village; Clackamas County including West Linn, Oregon City, and Milwaukie; portion of the Tualatin Basin including Beaverton, Tigard, and Tualatin; and portions of the Sandy and Clackamas Basins.
5/-Includes Alsea Basin portion of Benton County and Siuslaw Basin portion of Lane County.

Water Resource Base

SURFACE WATER HYDROLOGY

Because of the relationship of streamflows to water quality, an understanding of surface water hydrology and streamflow characteristics is fundamental to water quality management. Of particular concern are discharge volumes, time of travel, distribution of flows, and frequency of drought flows. The following description has been developed from streamflow data on the Willamette Basin. Analysis has been limited to projecting probable future streamflows based on recorded past flow conditions.

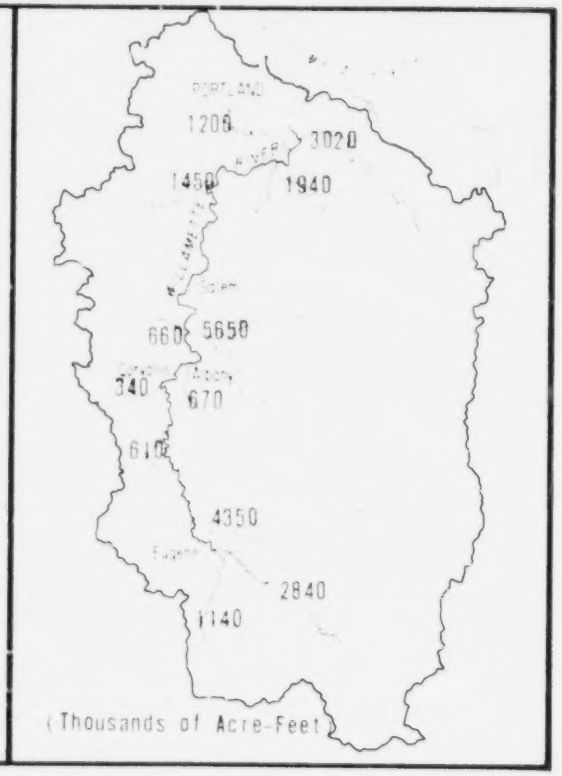
yield

The Willamette Basin has an average annual yield of 36 million acre-feet—nearly fifteen percent of the annual yield of the Columbia River. This flow is developed from twelve major tributaries. The eastern tributaries (Clackamas, Molalla, Santiam, Calapooia, McKenzie, and Middle Fork) drain 71 percent of the basin and account for about 75 percent of the total yield of the Willamette system.

runoff distribution

In general, the discharge pattern of the Willamette Basin streams agrees very closely with the precipitation pattern. Maximum flows occur between the months of November and April--a direct result of runoff from precipitation and melting snow. Minimum flows occur between July and October. In terms of volume, over 75 percent of the average annual yield occurs during the six wet months.

AVERAGE ANNUAL YIELD



As a rule, the streamflow regimen of tributaries is similar to that of the main stem Willamette with the exception that eastern tributaries (due to snow melt, groundwater storage, and regulation) maintain higher sustained flows through the dry season than the tributaries draining the coastal mountains. This distinction is particularly noticeable in the McKenzie and Yamhill Rivers, typical examples of the two types of streams. Discharge rates for average high and low monthly flows vary four to one (9,630 to 1,945 cfs) in the McKenzie and forty to one (5,950 to 99 cfs) in the Yamhill River. At present, authorized and constructed projects to store flood flows and regulate summer flows have a total storage capacity of only 2.2 million acre-feet, about 8.3 percent of the total annual yield.

low flow period

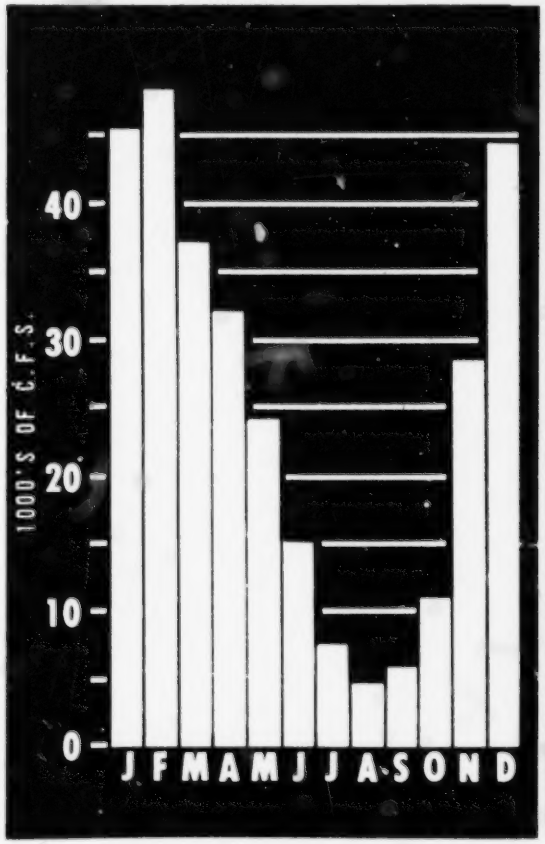
From the standpoint of water quality control, the low flow months of July, August, September, and October are the most important. In most of the basin, August is the critical month. The normal differences in magnitude between east-side and west-side tributaries becomes more pronounced during low flows; the average August flow of the five major eastern tributaries below the confluence of the Coast and Middle Forks amounts to about fifteen times that of the western tributaries.

design year

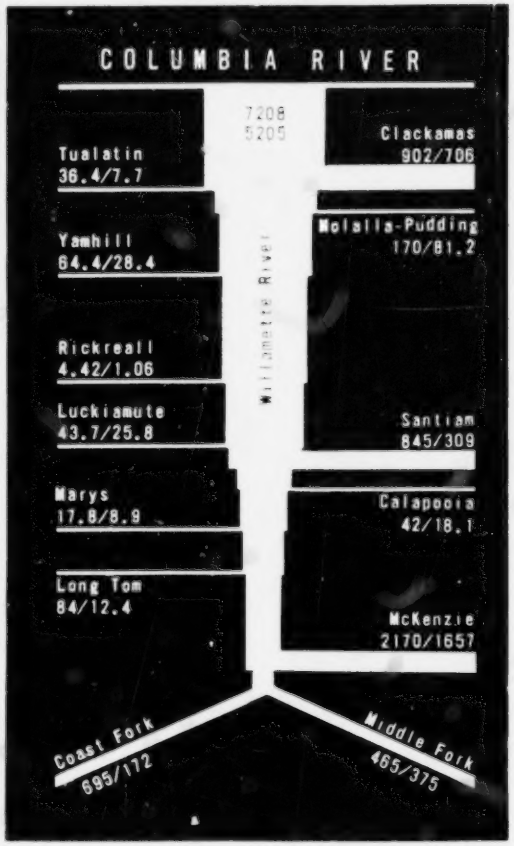
Studies to predict recurrence frequency of critical low flows were based upon recorded and correlated flows adjusted to reflect expected reservoir regulation. The flows which could be expected to occur at frequencies of two, five, ten and twenty years were determined for each major stream. As an example, a frequency analysis of the Willamette River at Salem indicates that, as the curve reaches a recurrence interval of ten years, it flattens out. There is, therefore, little difference between the once-in-ten year and once-in-twenty year drought flows.

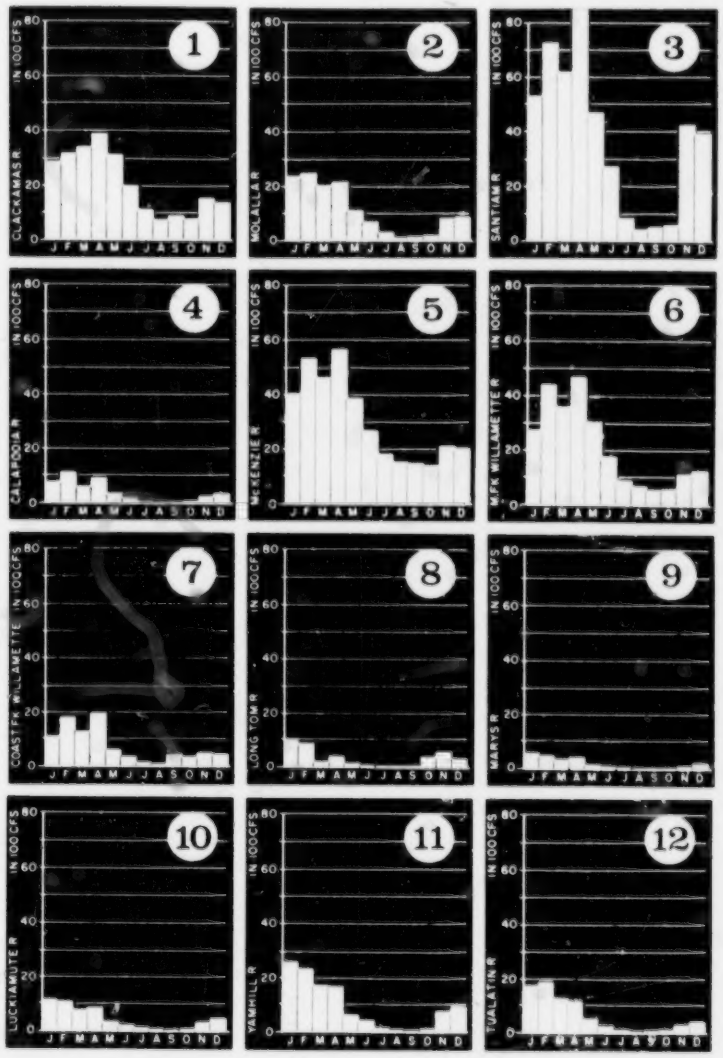
The design flow for establishing storage and waste treatment requirements was set as the drought which could be expected once in ten years. The once-in-ten year low flow very closely approximated recorded flows of 1941. The 1941 water year was, therefore, adopted as the design year for water quality considerations.

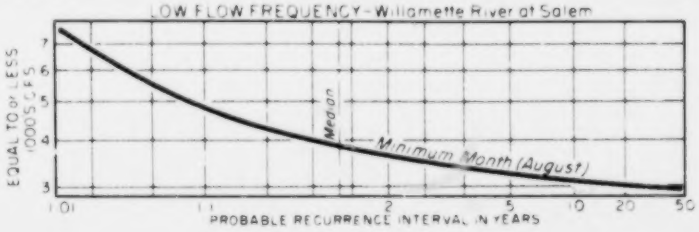
SALEM MONTHLY HYDROGRAPH

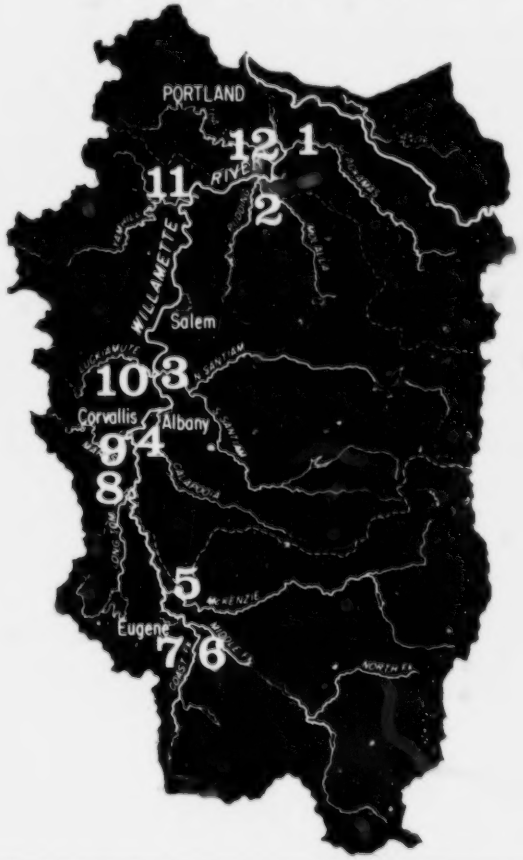


OBSERVED AVERAGE AND MINIMUM AUGUST FLOWS (cfs)




1
CLACKAMAS R.
2
MOLALLA R.
3
SANTIAM R.
4
CALAPOOIA R.
5
MCKENZIE R.
6
N.FK WILLAMETTE R.
7
COAST FK WILLAMETTE
8
LONG TOM R.
9
MARYS R.
10
LUCKIAMUTE R.
11
YAMHILL R.
12
TUALATIN R.
IN 100 CFS
0
20
40
60
80
J F M A M J J A S O N D


LOW FLOW FREQUENCY - Willamette River at Salem
EQUAL TO or LESS THAN 1000 CFS
7
6
5
4
3
Median
Minimum Month (August)
1.01
1.1
2
5
10
20
50
PROBABLE RECURRENCE INTERVAL IN YEARS


PORTLAND
12
1
11
2
WILLAMETTE RIVER
Salem
10
3
Corvallis
Albany
9
4
8
5
Eugene
7
6

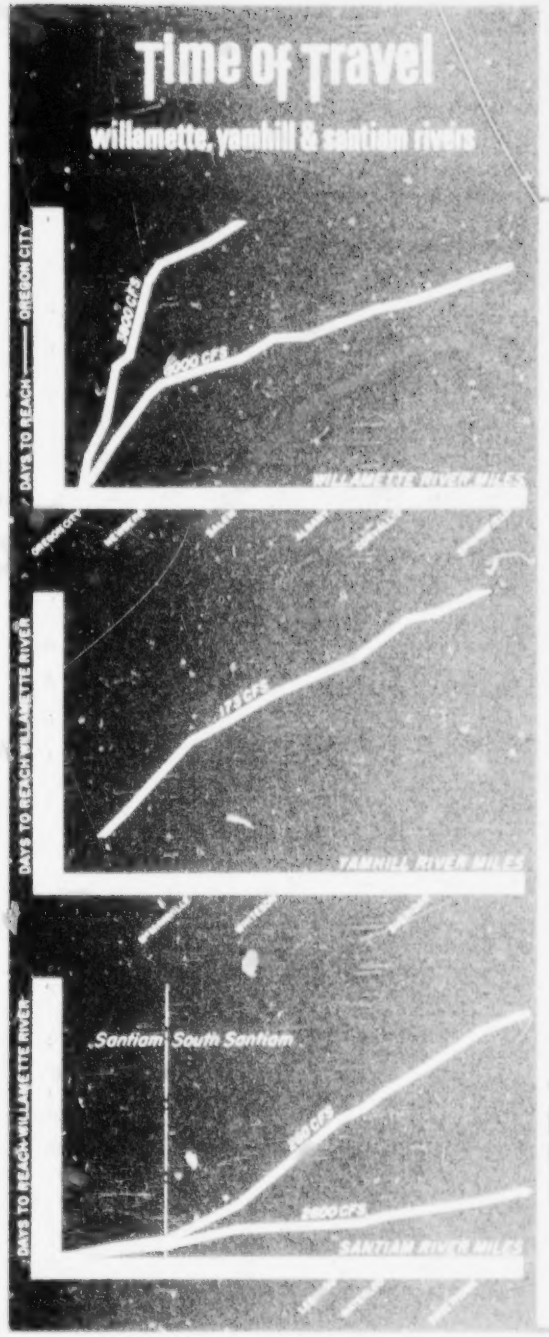
Stream profiles

Except for an abrupt drop at Oregon City, the profile of the main Willamette River is characterized by a relatively flat gradient, particularly from Newberg at the head of the 25-mile pool formed behind Willamette Falls through Portland harbor to the Columbia River. From Eugene to Corvallis, the average slope is 4 feet per mile; from Corvallis to Newberg, the average slope is 1.7 feet per mile; from Newberg to Willamette Falls, the drop is negligible; and below the falls to the south, the gradient is less than 0.2 feet per mile. The latter reach is subject to tidal influence and backwater effects from high stages of the Columbia.

In contrast to the main river, the tributaries of the Willamette have steeper slopes, particularly the east-side streams. Stream gradients in tributaries originating in the Cascades frequently exceed 50 feet per mile in the upper reaches and gradually lessen as they approach the valley floor. The Santiam River, typical of the eastern streams, has an average gradient of 22 feet per mile. The west-side tributaries are characterized by flatter slopes. The Long Tom, Tualatin, and Yamhill Rivers are primarily valley streams with hydraulic characteristics separable to the main Willamette River.

Time of Travel

Directly related to stream gradient and important to the determination of water quality and waste assimilative capacity, time of passage is an integral part of the hydrologic analysis. Time-of-travel data—that is, the time necessary for a particle of water to travel through a stated stream reach at various levels of flow—were obtained through combined studies with Federal and State agencies. In general, time of travel is shorter in east-side tributaries than in



the western streams of lesser slope. The Santiam and Yamhill Rivers are representative of the east- and west-side tributary streams, respectively.

The Willamette River above Newberg is a relatively rapidly flowing stream (one to two miles per hour), but below Newberg it consists of two deep, slow-moving pools. Under summer conditions, time of passage from Eugene to Newberg, a distance of 127 miles, is only three days. From Newberg to the Columbia River, a distance of 50 miles, time of passage is estimated to be eight days.

GROUNDWATER

Large supplies of groundwater are available in the Willamette Basin, generally in the lowland areas where development and need for water are, and will be, most extensive. The major groundwater reservoirs are the alluvial deposits making up the flood plains and terraces along the Willamette River and the major tributaries draining the Cascades. The permeable volcanic formations making up the higher Cascades provide good groundwater reservoirs, but the basalts and rhyolite soils of the western Cascades and the fine-grained sedimentary rocks of the Coast Range have a relatively low permeability and make poor aquifers.

yields

The highly permeable gravels which underlie the flood plains of the Willamette and larger tributaries provide yields of 1,000 gallons per minute to individual wells without excessive drawdown. The lava aquifers and the sand and gravel deposits that underlie the terraces have much smaller yields, but because they are more extensive, the aggregate withdrawal is greater than from the flood plain gravels. Those wells located on the recent unconsolidated sediments and formations of the Coast Range are generally of low yield (less than 10 gallons per minute per well) and have excessive drawdown.

use

Groundwater is an important source of supply for rural domestic, municipal, industrial, and irrigation water needs in the Willamette Basin. The largest withdrawals are for irrigation in the northern Willamette Valley, public supplies for small cities and suburban water districts, and for industries located along major streams and near cities. Water rights filed for groundwater use are in excess of 600,000 acre-feet per year, broken down as follows: irrigation 43 percent, municipal supply 30 percent, industrial 24 percent, and domestic 3 percent. It is estimated that only about half, or 300,000 acre-feet, of this amount is used annually. Groundwater is the source of about 27 percent of all water used in the basin.

future use

Nearly all the major groundwater reservoirs can supply appreciably larger yields. The highly productive gravels along the Willamette are so permeable that wells can be spaced closely without interference. Heavy precipitation and infiltration from the river provide adequate recharge. The amount of groundwater available beneath stream terraces is also believed adequate to support substantially greater withdrawals. Only in a few small places, as in the west-side business district of Portland and the Salem Heights area, have groundwater levels declined as yet; and even in these areas, there is no evidence of serious overdraft. However, it is anticipated that groundwater will serve the same proportion (27 percent) of total water used in the basin in the future, since high-quality surface sources are readily available in those areas where groundwater sources are suitable for development.

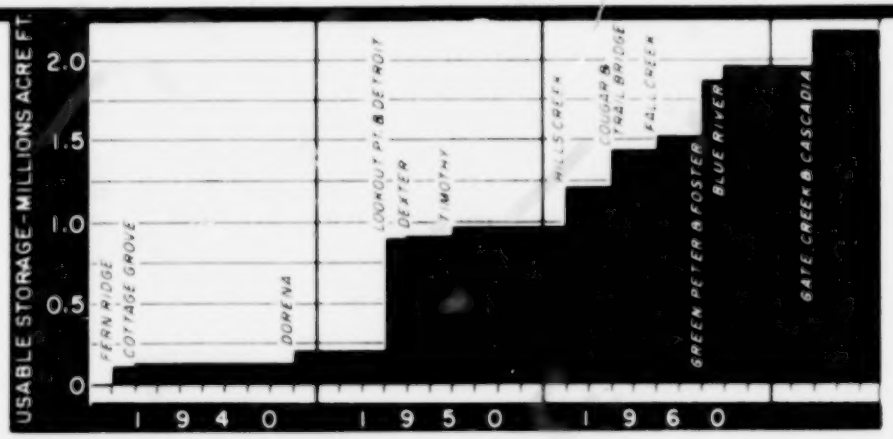
relation of ground and surface waters

The groundwater reservoirs of the basin are an important factor in sustaining streamflow, especially during the summer and fall. The very porous lavas along the crest of the Cascade Range absorb a large quantity of spring and winter runoff, which appears in the form of springs at lower elevations. These groundwater releases provide a large portion of summer flows of streams originating in the Cascades.

WATER RESOURCE DEVELOPMENT

The present state of water resource development in the Willamette Basin has evolved over the last three decades as a result of continuous study of flood control, navigation, and related resource needs. Initially authorized by the Flood Control Act of 1938 and repeatedly modified by subsequent acts, this development provides a system of multi-purpose reservoirs which regulate the flows of the Willamette and its tributaries.

At present, there are fourteen multi-purpose storage reservoirs authorized in the Willamette Basin. Eight of the fourteen are in operation. Together with three power reservoirs, these provide a usable storage capacity of 1,515,600 acre-feet. Reservoirs under construction will provide an additional 646,000 acre-feet of usable storage. Existing and authorized storage capacity of 2,161,600 acre-feet is about 8.3 percent of the annual 26 million acre-feet runoff of the basin. The purposes for which this storage has been allocated are limited to navigation, flood control, irrigation, and power. No storage is authorized for water quality



WILLAMETTE BASIN STORAGE PROJECTS

Project	Stream	Stream River Mile	Drainage Area[1] at Site	Usable Stor Cap Ac.-ft.	Purpose	Agency	Date in Oper.
Cottage Grove	Coast Fk. Willamette R.	29.7	104	30,000	FC	USACE	10 4 2
Dorena	Row River	20.7-7.5	265	70,500	FC	USACE	10 4 9
Hills Creek	Mid. Fk. Willamette R.	45.5	389	249,000	FC,P,I	USACE	7 6 1
Lookout Point	Mid. Fk. Willamette R.	19.9	991	349,000	FC,P,I	USACE	10 5 3
Dexter	Mid. Fk. Willamette R.	16.8	996	4,800	Rereg.	USACE	11 5 4
Fall Creek	Fall Creek, Mid. Fk. Will.	11.3-7.2	184	115,000	FC	USACE	10 6 5
Cougar	S. Fk. McKenzie R.	59.7-4.5	210	165,000	FC,P,I	USACE	11 6 3
Strube	S. Fk. McKenzie R.	59.7-2.5	216	3,000	Rereg.	USACE	Prop.
Blue River	Blue River, McKenzie R.	57.0-1.7	88	85,000	FC	USACE	10 6 8
Gate Creek	Gate Creek, McKenzie R.	41.4-0.4	50	50,000	FC	USACE	10 7 2
Carmen-Smith	McKenzie R.	87.6	161	—	P	EWEEB[2]	1963
Trail Bridge	McKenzie R.	81.9	184	12,000	Rereg.	EWEEB	1963
Fern Ridge	Long Tom River	25.7	274	109,200	FC,P,I	USACE	10 4 1
Holley	Calapooia River	49.7	99	90,000		USACE	Prop.
Green Peter	Middle Santiam River	11.7-40-5.7	277	333,000	FC,P	USACE	1 6 7
Cascadia	South Santiam River	11.7-48.3	179	145,000	FC		10 7 2
Foster	South Santiam River	11.7-37.7	494	33,000	Rereg.	USACE	10 6 7
Detroit	North Santiam River	11.7-49.2	438	340,000	FC,P	USACE	12 5 3
Big Cliff	North Santiam River	11.7-46.4	452	2,400	Rereg.	USACE	12 5 3
Dallas	Rickleall Creek	24.2		740	MI	Dallas City	6 6 0
Red Prairie	Mill Cr., S. Yamhill River	11.2-41-9.5		50,000	I,MI,QC	USBR	Prop.
Haskins Creek	Haskins Cr., N. Yamhill R.	11.2-25-3.1	6.9	730	MI	McMinnville	10 5 1
Scoggin Creek	Scoggin Cr., Tualatin R.	60-5.0	39	53,800	I,MI,QC	USBR	Prop.
Timothy Creek	Clackamas River	50.3-15.8	54.3	61,700	P	PGE[6]	6 5 6
Oak Grove	Clackamas River	53.0	131	—	P	PGE	1924
North Fork	Clackamas River	31.1	665	—	P	PGE	1958
Faraday	Clackamas River	26.2	665	—	P	PGE	[illegible]7
River Mill	Clackamas River	23.3	671	—	P	PGE	1911

1. Square miles. 2. FC-flood control, P-power, I-irrigation, MI-municipal and industrial, and QC-water quality control. 3. U.S. Army Corps of Engineers. 4. Eugene Water and Electric Board. 5. U.S. Bureau of Reclamation. 6. Portland General Electric Company.

WILLAMETTE RIVER BASIN PROJECTS

Existing and authorized water resource projects, located primarily on east-side tributaries, store 8.3 percent of the Willamette's annual runoff. Storage for water quality control is not authorized in the existing reservoirs.

Through the U. S. Army Corps of Engineers flood control program, [illegible] capacity has been increased substantially in the past three decades. [illegible] total storage capacity in the Willamette will be [illegible]

control, although incidental benefit results from releases for other purposes.

The U. S. Army Corps of Engineers estimates a potential 1,100,000 acre-feet of additional storage in the Willamette system, which would bring the total storage capacity to 12.5 percent of average annual runoff. The Bureau of Reclamation has proposed projects on the Tualatin and Yamhill Rivers and Rickreall Creek. The Corps of Engineers has proposed a reservoir on the Calapooia River, which is currently being studied. These projects include benefits for municipal and industrial water supply and water quality control; storage in earlier reservoirs was not allocated for these specific uses.

STREAM MANAGEMENT

Regulation of Willamette Basin flows by Federally constructed reservoirs is essentially controlled by the U. S. Army Corps of Engineers. The only reservoirs not under its jurisdiction are single-purpose reservoirs without significant storage for purposes other than power generation. Withdrawals from most of the major streams are subject only to the constraints imposed by water rights and are controlled by the user according to need.

The regulation of flows by the Corps of Engineers must be considered separately for the two periods into which each water year is divided with respect to the need for, or absence of, flood control operation.

(1) During the typical flood season from October through April, the operation of the system is analyzed daily; flow and stage data and near-future runoff forecasts are considered in determining reservoir operation. Outside of this critical operating period, flood control considerations are a constraint in reservoir operations only to the extent that certain pool levels must be achieved by certain dates.

(2) During the part of the water year not dominated by flood considerations, the reservoirs are operated according to pre-arranged criteria designed to serve water uses in the order of priority designated for each reservoir. An operation manual for each project specifies the rule curves and parameters for operation, based on license requirements and project formulation. Such considerations as desirable pool levels for recreation, flows for fish and navigation, and rate of change of flow are covered by the operation manual.

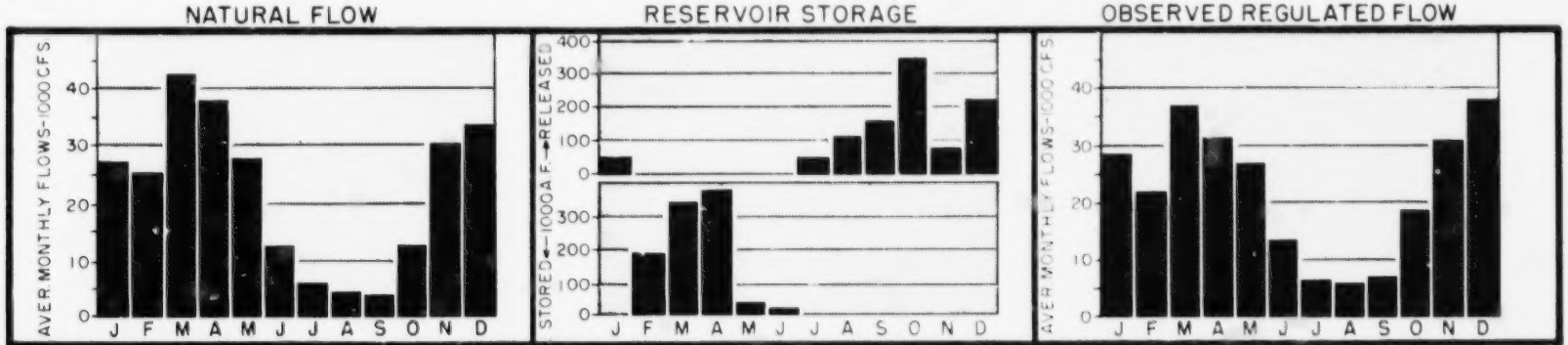
Release of water stored for electric power generation is controlled on a daily basis according to operating plans developed by the Northwest Power Pool. Consequently, high releases from the Willamette system are required in October and November when Columbia River streamflows are low.

Existing Federal reservoirs in the Willamette Basin do not have storage specifically allocated to water quality control; therefore, there are no authorized means of managing streamflow in response to pollution problems or water quality requirements. Streamflows provided for navigation, however, are of considerable assistance in improving water quality in the Willamette River; and, in the initial designation of such flows, their usefulness in improving water quality was recognized.

Present operation of the Willamette reservoir system results in a conflict of water uses in the basin. Operation to provide high level reservoirs for late

summer recreation and October power generation is not compatible with the need for reservoir drafting for quality control in the critical months of July, August and September.

The OSSA has recognized the undesigned benefit to water quality which results from flow augmentation for navigation by designing its waste removal requirements to reflect the minimum flow for that purpose of about 5,500 cfs at Salem.



Typical streamflow regulation effects: flood control operation at Willamette River dams reduces spring flows about 15 percent to augment summer flows by over 2,200 cfs. Maximum releases occur in October for power generation and flood control storage.

WATER RIGHTS

Water rights in Oregon are administered by the State Engineer. Appropriation is based on the prior right doctrine, and application may be filed with the State Engineer for any beneficial use. Beneficial uses established by State legislation are: domestic, irrigation, municipal, industrial, power, mining, recreation, wildlife, fish life, and pollution abatement. Appropriations for domestic and stock watering purposes are given the highest priority.

Categories of use are also described as consumptive or non-consumptive. Domestic, irrigation, municipal and industrial purposes are generally categorized as consumptive. In some instances, water used for power is diverted from the parent stream with no return and is, therefore, effectively consumed relative to the downstream reach. An example is diversion from the South Santiam at Lebanon with the return to the Willamette River at Albany.

Appropriation of water may be restricted by the following considerations:

1. Legislative reservation and dedication. Examples are the Bull Run and Sandy Rivers which were taken from further appropriation and dedicated as as municipal water sources for the city of Portland.

2. Designation by the Water Resources Board of the certain use (or uses) for which water may be withdrawn. The particular stream thereby becomes limited to the designated purpose, e.g., fish and wildlife, recreation, domestic, or other purposes.

3. Reservation by the Water Resources Board of a base flow. Rights may be granted after such an action but only valid during periods of flow higher than the established base flow or for use of water legally stored and released upstream from the point of diversion.

4. State Engineer's reservation and dedication for future municipal use in preference to subsequent appropriation for other purposes.

5. State Engineer's order regulating the use of groundwater in a critical area. The order may regulate all aspects of groundwater control. By statute, a critical groundwater area is one where the following have or may be reasonably expected to occur: (a) overdraft, (b) interference of two or more wells, (c) degradation of purity, (d) decline of level.

Conflict between users that results in civil court action may force adjudication of the affected stream. The final result of adjudication is a court decree listing the legitimate water users, the amount of water, priority, and other restrictions, if any.

The general procedure of an adjudication involves a survey or study of the

stream by the State Engineer, taking particular note of water uses and the facilities installed for its use. Upon completion of the State Engineer's survey, a notice is posted by certified mail to each person having expressed an interest in obtaining a water right. Following this, a court decree is established which finalizes the action. The watermaster then has a firm basis for policing all water withdrawals and uses. In the absence of adjudication, the watermaster can only police withdrawals based on existing rights and cannot, on a sound basis, dispute the legality of a withdrawal made by one claiming a vested right.

Adjudication is a time-consuming and expensive process. Estimated cost of complete adjudication of the Willamette system is approximately a million dollars.

willamette basin water rights status

Of the Willamette Basin streams, only the Tualatin and North Santiam Rivers have been adjudicated; the status and amount of water available for appropriation in other subbasins of the Willamette are impossible to determine. The OSWRB has established minimum flows for most streams, based on demonstrated need and tempered by historic flows. However, full exercise of existing rights might make satisfaction of these base flows an impossibility. There is a need, therefore, for adjudication of the Willamette Basin stream system.

Because of unadjudicated claims, water rights do not give a clear description of either current or contemplated water use in the basin. Water for municipal and industrial uses is drawn from power rights without allocation for such uses; many rights are in excess of the actual withdrawal from the stream; and many unused rights (as for mining) have not been removed from the records. Lack of information on the duration and time of year that rights are exercised further complicates the matter.

One illustration of the adjudication problem is power claims--the largest single class of water appropriation. Publishers Paper Company, Crown Zellerbach and the Portland General Electric Company have power claims for 30,155 cfs from the Willamette at Oregon City; summer flows at that point often drop below 6,000 cfs. Until this claim is adjudicated, all subsequent upstream claims and rights are uncertain. There are also significant power claims on many of the tributaries.

POWER CLAIMS - WILLAMETTE BASIN
(Not Included In Water Rights)

McKenzie River	1600 cfs
Long Tom River	25 cfs
Calapooia River	35 cfs
Santiam River	3668 cfs
Yamhill River	6 cfs
Clackamas River	6600 cfs
Willamette-Misc. Tribs	18 cfs
Willamette River	30155 cfs
	42107 cfs

GROUNDWATER RIGHTS SUMMARY

WILLAMETTE BASIN

Groundwater Area	(By Sub-basin)[2] (cfs) Domestic	Municipal	Industrial	Irrigated
Coast Fork Willamette	-	0.40	0.90	12.10
Middle Fork Willamette	-	27.20	0.10	6.40
McKenzie	-	16.30	0.70	40.10
Willamette River - Upper	-	[illegible].30	2.20	195.80
Other Upper Basin Areas	3.90	12.80	2.90	215.50
Scotts	0.50	61.80	7.60	310.50
Pudding	12.40	40.40	33.80	423.50
Tualatin	0.39	12.78	5.37	44.93
Clackamas	0.05	4.71	2.08	16.98
Columbia	1.22	36.17	129.05	47.50
Sandy	0.01	1.78	2.00	6.59
	18.47	218.24	186.81	1319.80

SURFACE WATER RIGHTS SUMMARY - WILLAMETTE BASIN OREGON

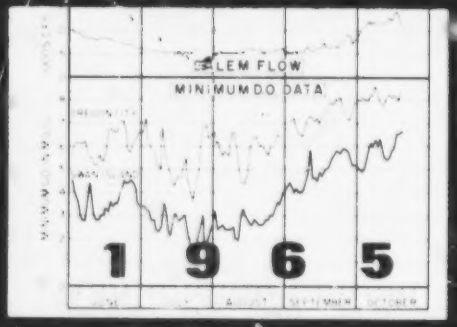
Sub-basin	WITHDRAWAL (cfs) Domestic	Municipal	Industrial	Irrigation	IN-PLACE Power	Mining	Fish Life	Recreation	Wild Life
Coast Fork Willamette R.	1,360	22,910	38,990	84,395	9,844	4,500	0,760	0,020	0,010
Middle Fork Will. R.	3,126	22,560	44,010	31,097	0		92,020	0,950	0
McKenzie River	5,237	312,360	95,820	1,493,655	10,383,274		155,460	0,760	0
Long Tom River	1,460	35,455	0,340	82,994	0,200		0,310	0,070	1,000
Calapooia River	0,142	0,670	0,490	38,934	181,220		0,350	0	0
Marys River	0,685	10,550	9,140	52,937	61,930		0,430	1,000	0,370
Luckiamute River	1,678	4,730	4,480	80,728	6,890		1,130	0	1,190
Santiam River	5,992	173,402	74,338	986,251	1,321,980		283,650	6,350	1,040
Rickreall Creek	1,092	14,000	0,205	28,502	0,040		0,017	0	0,520
Mill Creek	1,228	1,000	6,190	15,304	662,265		0,507	0,120	0
Yamhill River	3,698	38,650	24,190	234,860	0		7,230	0,120	0,070
Molalla River	2,780	23,400	18,110	333,09[illegible]	37,154		44,360	11,610	0,010
Tualatin River	9,100	25,220	31,715	148,96	69,230		12,400	0,452	0,340
Clackamas River	4,192	137,336	6,232	41,864	9,300,950		121,636	3,510	0,500
Misc. Will. Trib	5,534	7,920	5,610	91,121	22,407		10,380	0,420	2,220
Willamette River	3,707	28,060	95,530	271,482	0,940		0,809	36,800	0
TOTAL - Drainage Basin	51,011	858,223	155,960	4,328,927	22,058,124	4,500	731,449	68,182	7,270
Multnomah Channel	2,650	84,770	5,354	227,097	0		4,280	0,210	4,670
Sandy River	6,820	14,680[1]	29,900	9,563	14,680		46,550	2,790	0
Columbia River Misc.	1,600	1,090	2,240	0,275	17,250		80,000	0,360	0
TOTAL - Columbia	11,070	100,550	37,494	236,935	31,930		130,830	3,350	4,670
Total	62,081	958,773	493,454	4,565,862	22,090,054	4,500	862,279	71,542	11,940

1 *In addition, the total yield of the Bull Run River is, by legislative withdrawal, dedicated to Portland's municipal use.*

Minimum dissolved oxygen levels measured during the summer of 1965 reflect the influence of flow depletion on the water quality problem in the Portland harbor. Minimum levels of 1.7 mg/l were recorded.

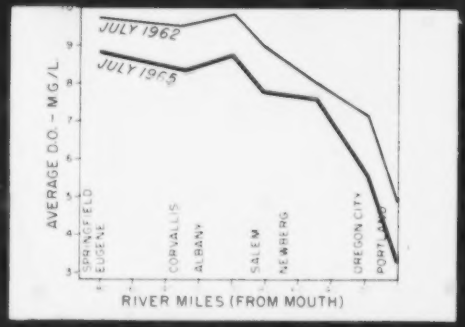
In the eleven years 1953 to 1963, DO in Portland harbor has usually been well below the 5 mg/l objective in summer, and has been at a level that approached septicity on a number of occasions.

Dissolved oxygen profiles show the effect of paper mill and other organic wastes on the oxygen resource. When flows are lower, as in 1965, their effect is heightened.



	June	July	August	September	October
1953	--	2.7 (2.0)	1.5 (0.7)	1.9 (0.9)	5.1 (3.2)
1954	6.7 (6.7)	5.5 (3.8)	2.9 (2.7)	4.3 (3.2)	5.1 (5.1)
1955	7.2 (5.9)	5.6 (4.1)	3.0 (2.2)	3.8 (3.3)	--
1956	--	4.0 (2.5)	3.0 (2.6)	4.3 (4.2)	5.1 (3.8)
1957	3.6 (2.8)	2.4 (0.8)	1.5 (0.6)	3.0 (1.4)	5.0 (2.9)
1958	4.8 (1.8)	4.4 (2.9)	3.4 (2.4)	4.5 (3.8)	5.9 (5.7)
1959	4.7 (2.9)	4.3 (1.5)	2.9 (2.2)	5.2 (3.1)	8.7 (8.7)
1960	5.8 (5.2)	4.4 (3.5)	3.6 (3.0)	4.8 (4.3)	5.4 (3.7)
1961	4.6 (3.0)	3.4 (1.9)	2.6 (1.8)	5.0 (4.1)	6.4 (5.1)
1962	6.1 (5.2)	4.4 (3.5)	3.6 (2.8)	3.6 (2.7)	5.5 (3.8)
1963	4.5 (2.5)	4.5 (3.4)	3.2 (2.0)	3.0 (2.0)	4.8 (3.4)

(Monthly minimums shown in parentheses) (Expressed in mg/l)



Water Quality

Water quality is both a measure of the usefulness of a stream and a consequence of the nature and degree of existing use. The critical period of water quality in the Willamette occurs during the summer months, when waste loads are high and streamflows are low; this period has, therefore, been used to describe present quality.

The following discussion is based on data from the OSSA, joint sanitary surveys by the FWPCA and OSSA, and from FWPCA monitoring stations in the Portland harbor and at Oregon City.

DISSOLVED OXYGEN

Main Stem--The Willamette River from its headwaters to Salem is a relatively shallow and fast-moving stream. Dissolved oxygen concentrations throughout this stretch are near saturation, ranging from 8 to 9 mg/l during the summer months. Below Salem, and particularly from Newberg at milepoint 50 to the mouth, the channel deepens, and dissolved oxygen levels diminish. A profile of average dissolved oxygen through the passage of the river shows progressive degradation from Salem to the mouth.

The most critical oxygen levels occur in the Portland harbor, where average summer concentrations range from 3 to 4 mg/l with occasional minimum daily readings of less than 2 mg/l. The harbor has a long history of low dissolved oxygen during the months of July, August, and September.

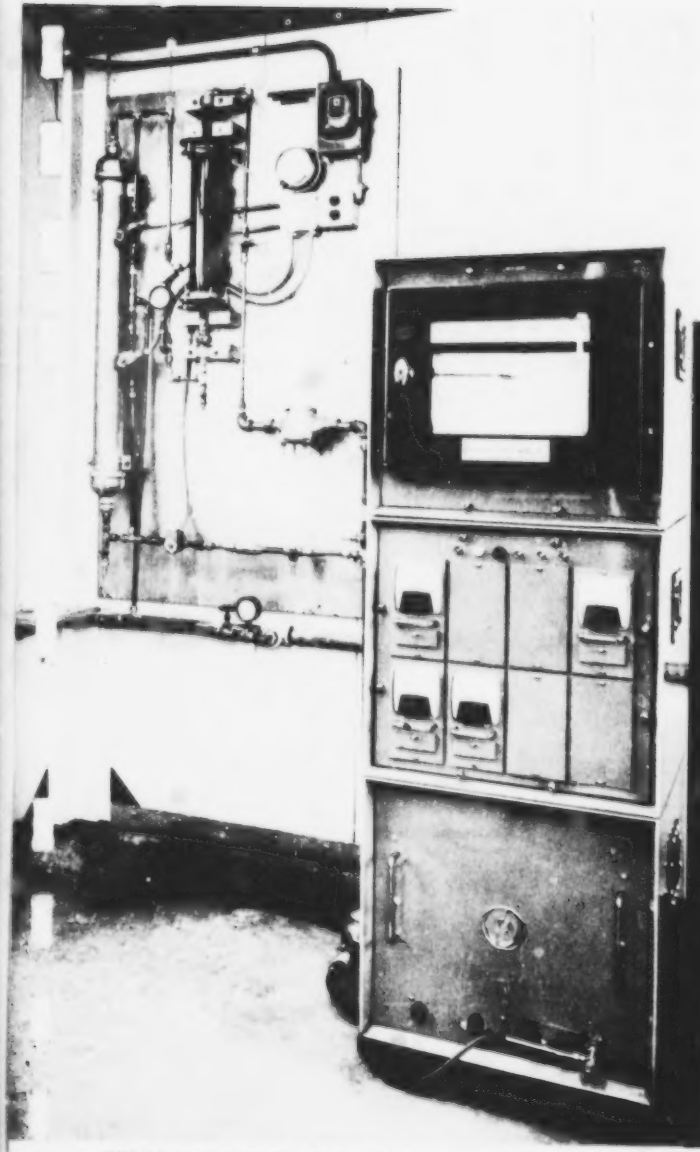
Dissolved oxygen concentrations in the Portland harbor are well below the 5 mg/l objective established for passage of salmonid fish species through the harbor.

Tributaries--Most of the tributaries maintain dissolved oxygen levels of at least 80 percent saturation throughout the summer months, and adequately meet fishery objectives. Average summer dissolved oxygen concentrations, except for several problem areas, range from about 7 mg/l to 10 mg/l. The only tributary streams having a major depression in dissolved oxygen are the South Santiam and Tualatin Rivers and Rickreall Creek.

The South Santiam below Lebanon has experienced severe depressions in dissolved oxygen for many years, and does not meet dissolved oxygen objectives. Minimum levels during recent summers have ranged from four to less than one mg/l below the Crown Zellerbach pulp mill.

TEMPERATURE

Main Stem--The Willamette River above Harrisburg is characterized by relatively low temperatures, with maximum values below 70 degrees (F) and average values ranging from 56 to 65 degrees during the summer months. Below Harrisburg, temperatures do not always meet fishery



FWPCA permanent monitoring stations at Portland harbor and Oregon City provide management agencies with a continuous record of lower Willamette water quality.

requirements, due to solar radiation on the exposed valley floor. Maximum temperatures exceed 70 degrees and averages range from 68 to 71 degrees.

Tributaries--Maximum temperatures of over 70 degrees with peak temperatures in excess of 80 degrees occur in the lower reaches of tributaries originating in the Coast Range. Major tributaries from the Cascades are characterized by lower temperatures, generally not exceeding 70 degrees.

The relatively deep reservoirs--like Detroit and Lookout Point--are thermally stratified during the summer with temperatures ranging from 70 degrees (F) at the surface to 45 degrees at the the reservoir bottom.

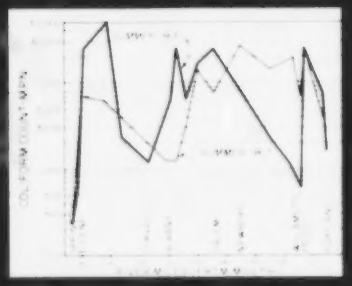
SUMMER STREAM TEMPERATURES
(Degrees Fahrenheit)

	July			August			September		
	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave
Main Stem Willamette River at:									
Harrisburg	72	52	64	71	59	65	68	53	61
Corvallis	76	60	68	73	62	68	68	63	65
Albany	77	53	68	76	58	68	60	52	62
Salem	78	56	68	75	55	68	75	52	63
Wilsonville	77	52	68	77	61	69	71	53	62
Oregon City	79	59	71	79	64	71	72	54	66
Portland (Steel Bridge)	79	59	70	77	64	71	70	56	65
Willamette River Tributaries:									
Coast Fork Willamette near Goshen	76	50	66	75	53	63	72	54	63
Middle Fork Willamette at Jasper	69	52	60	68	55	61	65	57	61
South Fork McKenzie above Cougar	60	47	53	57	47	52	53	44	49
McKenzie near Coburg	68	47	61	68	47	61	63	48	56
Long Tom at Monroe	81	53	70	80	63	71	74	53	64
Marys River at Philomath	80	46	66	77	53	65	73	48	61
Little North Santiam at Mehama	80	45	66	75	52	64	68	49	57
North Santiam near Jefferson	70	50	63	68	50	61	64	49	57
Middle Santiam at Foster	77	47	65	76	57	66	71	49	60
Santiam River at Jefferson	74	48	61	70	55	62	68	51	59
Luckiamute River near Hoskins	77	45	64	71	52	61	66	44	55
Rickreall Creek near Dallas	77	46	64	74	54	64	69	46	58
South Yamhill River near Willamina	81	48	68	79	58	68	73	49	61
North Yamhill River at Pike	79	46	66	76	55	65	70	46	58
Molalla River at Canby	82	47	68	81	59	70	70	46	62
Tualatin River at West Linn	83	51	70	80	60	69	76	53	65
Clackamas River at Cazadero Dam	63	53	58	62	54	58	60	48	54
Clackamas River at Estacada	70	46	61	69	53	60	65	45	55

Source: U. S. Geological Survey, thermograph and spot observations-period 1951 to 1963.

Water temperatures exceed salmonid fish requirements in many reaches of the Willamette and west-side tributaries. Major tributaries originating in the Cascades have lower stream temperatures.

The bacteriological quality of most reaches of the Willamette River is unsatisfactory for water-contact recreation; however, MPN have been lowered through the completion of secondary waste treatment facilities along the main stem.



BACTERIOLOGICAL QUALITY
August-September 1962

Tributary	Sampling Point (River Mile)	Observed* (Coliform Count per 100 ml)
Coast Fork	18	3,820
	10	1,370
	5	215
Middle Fork	7	100
McKenzie	4	115
Long Tom	7	6,800
Marys River	1	16,000
Calapooia	1	2,900
South Santiam	20	4,400
	17.5	4,900
	16.1	34,000
	11	38,000
	8	21,000
Rickreall Creek	2.5	103,000
Yamhill	5	10,000
Pudding	5	2,100
Molalla	3.5	8,600
Tualatin	0	6,300
Clackamas	1	600

* MPN per 100 ml.

Except for headwater reaches, the bacteriological quality of most Willamette tributaries exceeds the recommended maximum of 1,000 MPN.

TOTAL DISSOLVED SOLIDS

Maximum Concentration	Eugene Aug. 1963	Salem Sept. 1962	Portland Dec. 1963
Total Dissolved Solids, ppm	74	83	112
pH	6.6	6.9	6.9
Hardness, ppm $CaCO_3$	16	21	25
Alkalinity, ppm $CaCO_3$	31	22	53
Sulphate	1.5	3	1.5
Chloride	4.5	3	9.5
Nitrogen (ammonia) ppm	0.39		1.34
Nitrogen (nitrates) ppm	0.10		0.12
Phosphorus (PO_4) ppm	0.01		0.01
Sodium		4	
Silica (SiO_2)		16	

Total dissolved solids in the Willamette system are well within the drinking water limits recommended by the U. S. Public Health Service.

BACTERIA

Main Stem--The bacteriological quality of the main stem Willamette below Springfield is highly variable but generally unsuitable for water-contact recreation. Total coliform densities throughout the main stem range from 1,000 to 50,000 MPN (most probable number of coliform bacteria per 100 ml), with occasional maximums as high as 70,000 MPN. Most levels are considerably above the recommended bacteriological minimum of 1,000 MPN for water-contact recreation.

It should be noted that the main peaks occur below major service areas where substantial municipal wastes have been discharged. An improvement in bacteriological quality below Salem between 1963 and 1965 reflects the completion of secondary waste treatment facilities with improved interception of wastes. However, the 1965 profile indicates that bacterial levels are at present unsatisfactory for water-contact recreation in almost the entire main stem Willamette.

Tributaries--The bacteriological quality in the lower reaches of most tributary streams is unsatisfactory for swimming and other water-contact recreation. The following table shows the bacterial densities in Willamette tributaries during the summer of 1962. Only the Middle Fork, the McKenzie, and the Clackamas meet bacterial objectives throughout their length. The upper reaches of most tributaries--above major municipal waste sources--are of excellent bacteriological quality.

DISSOLVED MINERALS

Main Stem--The mineral quality of the main stem Willamette is uniformly good and, even under the most stringent criteria, suitable for all uses. Maximum concentrations of dissolved solids increase from Eugene to Portland, but mineral levels--maximum dissolved solids about 100 ppm--are well within U. S. Public Health Service drinking water standards.

Nitrogen and phosphorus levels are well below the maximum levels listed by the drinking water standards. Phosphorus concentrations remain well below 0.01 ppm. However, there is enough of these nutrients to promote the growth of algae.

Tributaries--Mineral quality of Willamette tributaries is excellent and suitable for all uses.

OTHER QUALITY FACTORS

suspended solids

Sediment transport and suspended organic matter such as fiber from pulp mills create periodic water quality problems in several parts of the Willamette Basin. In periods of low discharge, the river carries almost no suspended matter; however, sediment concentrations increase in most tributaries and in the main stem in times of high runoff. Excessive fiber and other settleable solids contained in pulp and paper mill effluents add to bottom sludge deposits and exert a considerable demand on the dissolved oxygen resource of the Lower Willamette and Portland harbor.

biological slimes

Biological slimes, including *Sphaerotilus*, create nuisance conditions for sport fishermen in the McKenzie River and Lower Willamette by fouling lines and destroying fish habitat. These growths are stimulated by the nutrients present in pulp and paper mill effluents.

CHAPTER THREE

ROLE OF WATER

The waters of the Willamette Basin are suitable for a wide variety of uses such as wildlife, recreation, irrigation, hydroelectric power, domestic, municipal and industrial water supply, and aesthetic enjoyment. The following examination of these uses and their quality requirements serves as the basis for a management program to serve present and future needs of the residents of the basin.

Water Uses

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

Water supply of industries and municipalities is a use which is particularly relevant to a study of water pollution control. Not only is the quality of supplied water an important consideration, but the waste discharges that create the major adverse impact on water quality correspond quantitatively with the intake of water by municipal and industrial systems.

Municipal and industrial water demands for the Willamette Basin in 1960 averaged nearly 380 million gallons a day (mgd) with municipalities using about 130 mgd and industries about 200 mgd. The distribution of this demand by service area shows that, in general, uses is concentrated in the four major service areas which account for about 90 percent of the total demand.

Statistical analysis of water supply patterns in the Pacific Northwest indicates that municipal demand in the Willamette is exerted at an average rate of 150 gallons per capita per day. The figure includes a "normal mix" of domestic, commercial and light industrial users characteristic of those connected to municipal systems. Peak monthly demands vary with climatic conditions and average about 185 percent of the average monthly demand.

Major industrial users in the Willamette are pulp and paper, forest products, food processing, and aluminum refining. Industrial demand, other than for food processing, shows little seasonal variation.

Surface water supplies are used to meet over 75 percent of total municipal and industrial water demands; about 90 per-

cent of municipal water needs and about 50 percent of industrial needs are supplied by surface sources. Major sources are the McKenzie, Santiam, Clackamas, Willamette, and Bull Run Rivers. Groundwater is readily available in the lower basin and is used by some industries, although surface water supplies major industrial users in the lower basin.

The quality of raw municipal and industrial water is considered to be generally good. Mineral quality of surface waters is excellent--well below the maximum limits recommended by the U. S. Public Health Service--and although bacterial quality is poor in some areas, MPN's of coliform organisms are well within the capabilities of modern water treatment technology. The most bothersome quality problems are turbidity, taste, and odors. Localized groundwater quality problems include surface contamination, salinity, hardness, and iron.

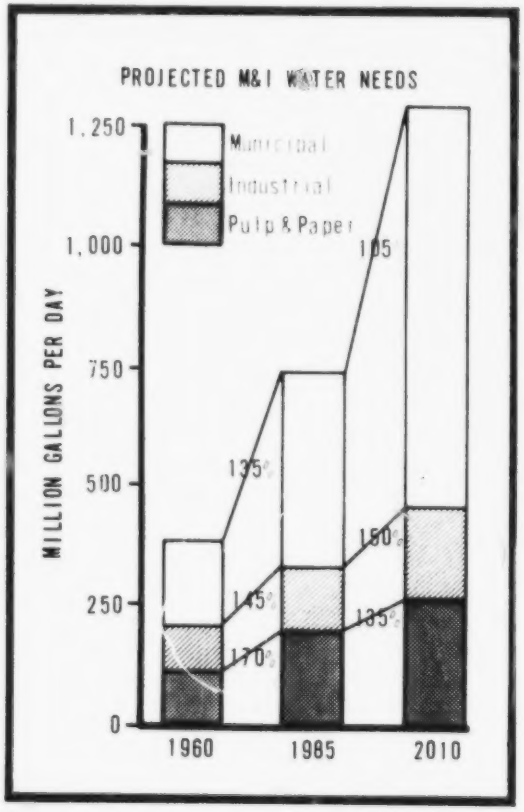
Most municipally supplied water in the basin receives minimal treatment, in part because of the general availability of protected watersheds. Of the population served by municipal surface water supplies, 75 percent receives water treated only by chlorination. Increased use of watersheds for recreation, and the water quality deterioration associated with increased suburban and industrial development, have led to mandatory disinfection of most surface supplies.

1960 MUNICIPAL AND INDUSTRIAL WATER SUPPLY DEMAND

Area	1960 Population		1960 Water Demand			
	Population in 000's	Total Basin	Municipal* (MGD)	Industrial** (MGD)	Total (MGD)	Total Basin
Major Service Areas						
Portland						53.5
Salem	90		16.2			10.4
Albany-Corvallis	52	4.5	9.4			
Eugene-Springfield	103	8.9	18.5			
Subtotal	920	79.4	165.6			88.9
Minor Service Areas						
Newberg	6	0.5	1.1	5.6	6.7	1.8
McMinnville	9	0.8	1.6	0.4	2.0	0.5
Woodburn	5	0.4		2.1	3.0	0.8
Silverton	5	0.4				
Cottage Grove	5					
Oakridge	3	0.3	0.5			
Subtotal		2.8		21.3	27.2	7.2
Other						
Total	1,159					

*Municipal water demands are based on a statistical [illegible] water supplies [illegible] Year 2020, Working Paper No. 54, Columbia River and Comprehensive Project--[illegible] showed a per capita water need in the Willamette Basin [illegible] gallons per capita per day.

**Industrial water demands are based on inventory data where available [illegible] and forest products [illegible] by Willis G. Eichberger in Industrial Water Use, a USPHS publication.



The Oregon State Board of Health requires complete treatment of water from surface sources, excepting well-protected watersheds such as Bull Run, which supplies Portland.

Projections of future water supply requirements indicate that the Willamette Basin's needs may be expected to increase more than three-fold by the year 2010. This projection reflects an anticipated increase in per capita municipal demand to 210 gallons by 1985 and 230 gallons by 2010. Future industrial demands are forecast on the basis of production projections and employment growth. The composition of water demand is expected to change somewhat, with municipal requirements surpassing industrial use in the future. Use is expected to continue to be concentrated in the four major service areas.

While the steadily mounting need for water will not strain the abundant water resources of the Willamette Basin, localized supply difficulties are certain to emerge. Although the total supply of water is available to meet demands well into the next century, the capacity of existing sources to satisfy future needs at the necessary times and places is highly questionable. Certainly storage capacity must be developed in increasing measure for water supply purposes. The coincidence of peak water demands with summer low flow periods makes increased storage for water supply purposes a fast approaching necessity. A good portion of the need for storage for water supply can be met by Federal multi-purpose reservoirs.

SUMMARY OF MUNICIPAL WATER SUPPLY SOURCES AND TREATMENT
WILLAMETTE BASIN, OREGON

Source and Treatment	Number of Municipal Facilities	Number of Developed Sources[1]	Population Served Thousands	Percent of Total
SURFACE				
No treatment	12	22	6	0.5
Disinfection	42	61	750	75.0
Coagulation, Sedimentation disinfection and filtration	9[2]	13	143	14.5
	63	96	899	90.0
GROUND:				
No treatment	47	93	42	4.0
Disinfection	25	66	57	6.0
Filtration and disinfection	--	--	--	--
	72	159	99	10.0
Total all Sources			998	

1/ Facilities with sources other than water purchased from other systems, for distribution.

2/ Total treatment plant capacity approximately 100 mgd.

Surface water is the primary source of municipal water supply. Complete treatment is required of surface supplies which are not well protected; however, disinfection by chlorination is the only treatment of 75 percent of the present supply for the basin.

PROJECTED MUNICIPAL AND INDUSTRIAL
WATER SUPPLY REQUIREMENTS FOR SERVICE AREAS
(mgd)

		1960	1965	1985	2010
Portland	Municipal	121.5	151.5	271.0	535.0
	Industrial	80.6	85.6	105.1	134.0
Salem	Municipal	16.2	21.2	43.3	95.5
	Industrial	22.9	32.0	45.8	81.6
Albany-Corvallis	Municipal	9.4	12.4	28.0	64.0
	Industrial	38.1	63.0	67.0	100.0
Eugene-Springfield	Municipal	18.5	22.1	36.3	72.2
	Industrial	28.2	44.0	57.1	69.5
McMinnville	Municipal	1.6	1.7	2.5	4.1
	Industrial	0.4	0.5	0.8	1.6
Woodburn	Municipal	0.9	1.1	2.3	4.1
	Industrial	2.1	3.1	4.2	8.4
Silverton	Municipal	0.9	1.1	2.1	3.7
	Industrial	0.7	0.8	1.4	2.8
Newberg	Municipal	1.1	1.6	3.6	8.7
	Industrial	5.6	6.6	11.2	19.1
Cottage Grove	Municipal	0.9	1.0	1.7	3.9
	Industrial	11.5	11.9	13.6	15.3
Oakridge	Municipal	0.5	0.6	1.1	2.5
	Industrial	1.0	1.0	1.2	1.3
Other		14.5	14.5	27.0	50.4
Total		377.1	477.3	726.3	1,277.7

Under the provisions of the Water Supply Act of 1958 (P. L. 500), space may be reserved, on a reimbursable basis, in Federal reservoirs to supply municipal and industrial water requirements. Effectiveness of the act, however, is limited by the incapacity of most municipalities and industries to gage their long-term water supply needs during the planning phase of Federal projects. Legislation which would enable the State of Oregon to contract for storage on the behalf of the ultimate municipal and industrial users in a watershed would do much to insure that growing water supply needs do not create critical problems for potential Willamette Basin users, and provide economies by meeting municipal and industrial water supply requirements coincidentally with those of other purposes for stored water.

FISHERIES

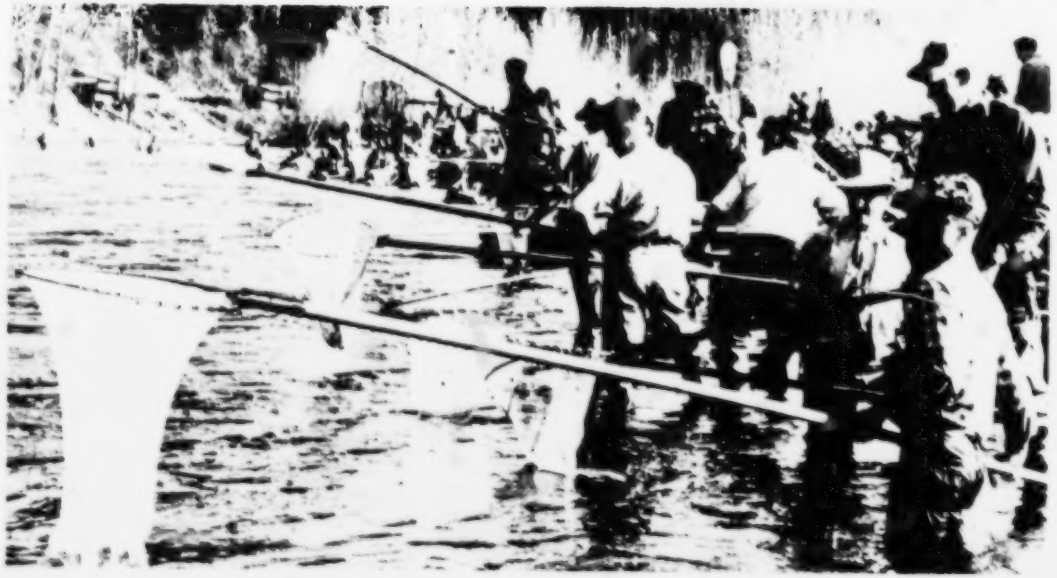
One of the outstanding uses of the Willamette River and its tributaries is the production of anadromous fish for the sport and commercial fisheries of the Willamette and Columbia Rivers and the Pacific Ocean. Large populations of salmon and steelhead, highly prized by sport anglers and commercial fishermen alike, make the Willamette fishery an important economic factor. It should also be noted that the Willamette is a "nursery", providing many of the fish for the commercial fishery in the ocean and the Columbia River. Moreover, the abundance of fast moving, sparkling clear streams in the headwater areas provides an excellent habitat for the delicate salmonid species and an abundance of fishing opportunities to the sportsman.

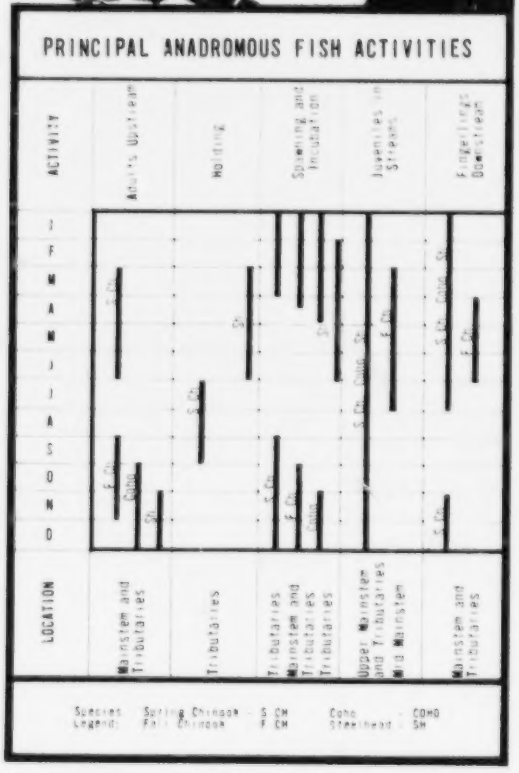
Game and food fish found in the Willamette Basin are the anadromous salmon (spring chinook, fall chinook, and coho), steelhead trout, resident species of trout, and warm-water game fish. Sturgeon and shad are also present downstream from Willamette Falls.

An inventory of spring chinook in the Willamette River is available from counts made annually at Willamette Falls by the State Fish Commission and from the annual sport fishery survey made jointly by the State Fish and Game Commissions. The average annual run into the Willamette during the period 1946-1961 was 51,000 fish. The average escapement upstream past Willamette Falls was 36,100 fish, with an additional 2,500 fish entering the Clackamas River. (The difference between the run and escapement--12,000 fish--is the sport catch.) Accurate estimates of coho and steelhead are not available, but their numbers are not large at the present time.

Dissolved oxygen and temperature levels are important to the migration and spawning of anadromous fish and the maintenance of fish activity in the Willamette Basin. At present, adult salmon and steelhead migrate upstream through the Portland harbor into the Willamette main stem and tributaries throughout the year, except for the period of about July 1 to August 1. (Future runs of summer steelhead, from fingerlings already released, will migrate during July.) Spring chinook hold in deep holes in the larger tributaries near the spawning grounds until fall spawning time. One or more of the species are spawning on gravel riffles in the accessible upper reaches of all the major streams and their tributaries from September 15 to May 15. Depending on water temperature, the eggs and fry incubate in the gravel for five to six months; juvenile fish then rear in the main stem and tributaries for three

North Santiam River





It should be noted that at all times of the year some anadromous fish activity can be expected.

mouths, in the case of fall chinook and coho, and up to two years for steelhead. Most of the downstream migration to the larger tributaries and the ocean occurs during higher-flow periods of the fall and spring, but some movement takes place in all months. Significant numbers of juvenile salmonids are to be found in the main stem, including Portland harbor, during all seasons of the year. Trout, warm-water game fish, and sturgeon are also found in many of the sage areas.

Fish produced in the Willamette River contribute to significant sport and commercial fisheries. It is estimated that about 25 percent of the Columbia River run of spring chinook is produced in the Willamette Basin. These fish provide for an intensive sport fishery in April-June from the mouth of the Multnomah Slough upstream to Oregon City. The average annual catch in the Portland harbor area is 12,000 fish, averaging 17.5 pounds per fish. Angling intensity in this area ranges from 62,000 to 138,000 angler days per year. The average annual catch for the entire basin is 17,000, as reported by the State Game Commission. The average annual steelhead catch is 1,600 fish.

Fishing pressure has been increasing steadily in Oregon, a function of increased incomes and leisure time as well as improved accessibility to the State's water bodies. During the 1950's the number of Oregon sport fishing license applications rose at a rate of six percent annually, or about three times as fast as population. In 1950, 451,000 licenses which permitted fishing were issued, indicating that about one-third of the population of licensing age had a desire to fish.

An Oregon State University study in 1965 estimated that total sport fishery use in the Willamette Basin was a minimum of 1.0 million angler days by Oregon residents. The major portion of this use occurred on the main stem, Clackamas, and McKenzie Rivers. Such tributaries as the Long Tom, Coast Fork, and Santiam also received considerable use.

Not to be ignored is the heavy use of the basin's streams by tourists who come

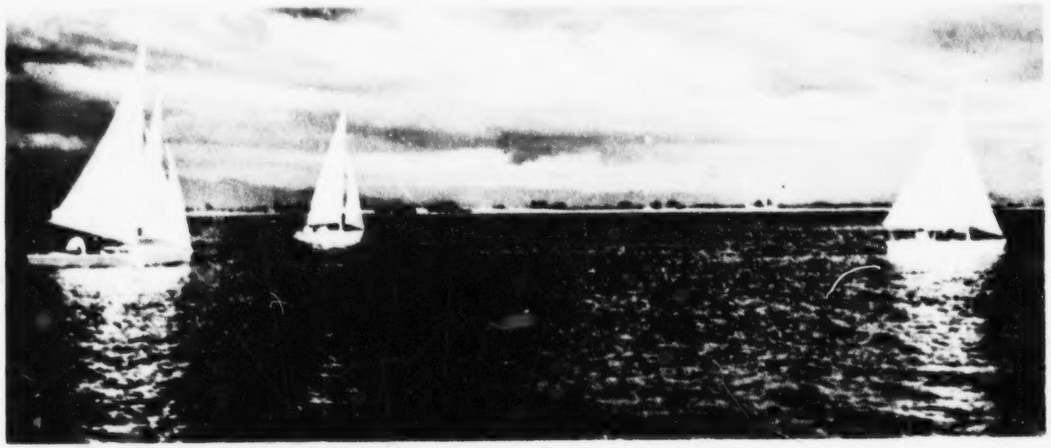
to Oregon to take advantage of the fishery resource. Some of the most popular trout fishing areas in the Pacific Northwest include the McKenzie and North Santiam Rivers, Clear Lake, Hills Creek, Dorena and Detroit Reservoirs. As an example, the Oregon State Game Commission estimates that 111,700 anglers caught 310,300 trout in Detroit Reservoir in 1963. Numerous high lakes also produce good trout catches. Areas most heavily fished for warm-water game fish are Fern Ridge and Cottage Grove Reservoirs and the Long Tom Rivers.

The State and Federal fishery agencies have embarked on a program to develop the large anadromous fish production potential in the Willamette Basin which is not presently utilized. The principal reasons for delay in this development have been insufficient water quality in Portland harbor and inadequate facilities for upstream fish passage. Construction will soon begin on a new fishway facility at Willamette Falls, costing $2 million.

New runs of fall chinook and coho salmon are being developed by mass plants of fingerlings into the main stem and tributaries. The returning adult fall chinook will enter the Willamette River beginning in mid-August and spawn in the main stem above Newberg and the lower reaches of major tributaries, including the Santiam and McKenzie. Summer steelhead are also being released into the Santiam River; the adult fish will pass through the Lower Willamette in July, August, and September.

Conservative estimates of potential run sizes under the new program and facilities are: spring chinook-67,900, fall chinook-90,000, coho-90,000, steelhead-30,000. The Bureau of Commercial Fisheries estimates the gross value of these fish to be near $4 million a year, three-quarters of which is allocated to commercial fishing.

As one of the few remaining salmonid fish production areas in the Columbia Basin, the Willamette River must be managed to permit development of its full fishery potential. The critical reach of the river is the Portland harbor, where seasonal low dissolved oxygen levels have caused pollution "blocks" to the passage of migrating salmon. Some spawning and rearing grounds in the upper reaches and tributaries have also been endangered by pollution. The establishment of a base flow for navigation purposes has enabled the partial restoration of the Willamette fishery. However, increased future demands on the river could place fish runs in jeopardy. Therefore, the water quality of the Willamette must be assured, through waste treatment and flow regulation, at levels which provide a healthy environment for fish.



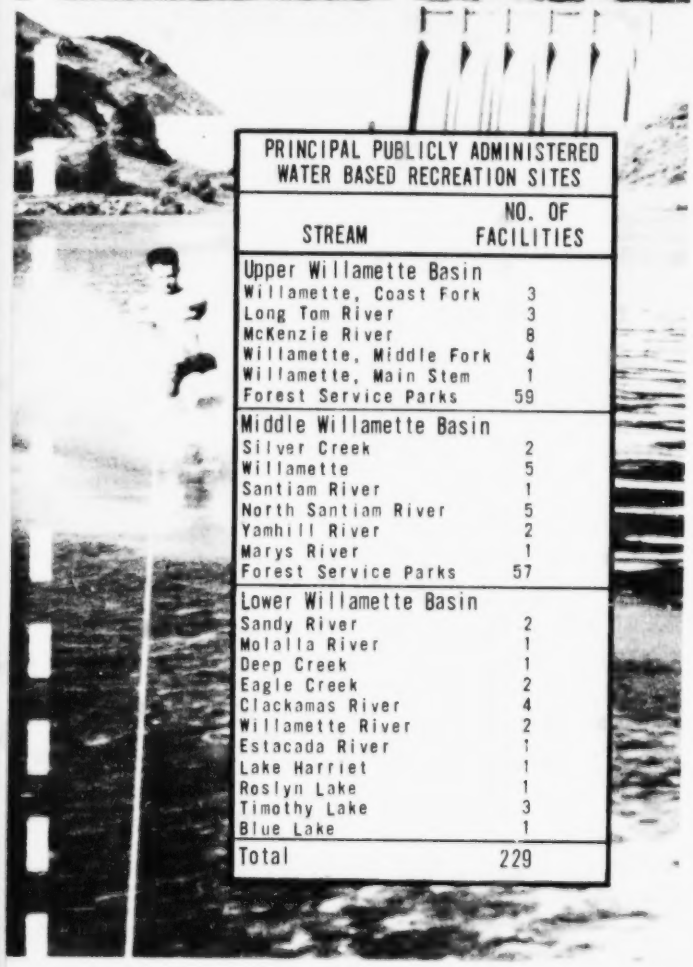
MAJOR WATER RECREATION INDEX

Purpose of Visit	1958	1959	1960	1961	1962	1963
Swimming	100	145	249	224	330	678
Fishing	100	140	149	162	154	157
Boating	100	20	175	183	607	272
All Recreation	100	104	119	137	152	141

Placed in the form of an index, the rise in numbers of recreationists [illegible] visiting national [illegible] shows the rapid growth of recreational use of water. In 1963, 1.17 million of the total 1.7 million recreationists were attracted by, or used, some type of water-based activity.

RECREATION

Recreational use of the Willamette Basin water bodies is intense--a function of established recreational habits and a large, growing, urbanized population. Other than game fishing, recreational water uses include boating, swimming and bathing, skin diving, and water skiing.



PRINCIPAL PUBLICLY ADMINISTERED WATER BASED RECREATION SITES

STREAM	NO. OF FACILITIES
Upper Willamette Basin	
Willamette, Coast Fork	3
Long Tom River	3
McKenzie River	8
Willamette, Middle Fork	4
Willamette, Main Stem	1
Forest Service Parks	59
Middle Willamette Basin	
Silver Creek	2
Willamette	5
Santiam River	1
North Santiam River	5
Yamhill River	2
Marys River	1
Forest Service Parks	57
Lower Willamette Basin	
Sandy River	2
Molalla River	1
Deep Creek	1
Eagle Creek	2
Clackamas River	4
Willamette River	2
Estacada River	1
Lake Harriet	1
Roslyn Lake	1
Timothy Lake	3
Blue Lake	1
Total	229

In addition, picnicking and camping are popular along the banks of the basin's streams and lakes. Every stream and major reservoir in the Willamette Basin provides some or all of these uses, despite instances of low water quality in many areas of major population concentration.

User statistics are only partly available to measure the growing intensity of demand for public recreational facilities, and these are more useful as an index of trends than as an indication of the over-all dimensions of recreational use of water. Major rivers in the Willamette system are all accessible at a number of points where no user count is made, so a large number of users is not represented in tabulations.

An impressive rise in the number of recorded users indicates clearly that the demand for water-oriented recreation is increasing. One significant example of this trend is the increase in attendance at Willamette Basin State parks with water-oriented activities.

Day visitors to these State parks have doubled between 1960 and 1964, a rate of about 19 percent per year. Available statistics on recreation activities indicate a more rapid rise in water-based recreation in the Willamette Basin than in outdoor recreation activities as a whole. The tabular index of estimated recreational use of Forest Service facilities in the Willamette Basin for the period 1958-1963 supports this conclusion.

Forest Service data also verify the recreational desirability of waterside locations. About 90 percent of the forest camps and picnic sites are at waterside locations, and an estimated 95 percent of picnicking and camping visits occur on such sites. Water-connected recreational visits to Forest Service facilities in the Willamette Basin are estimated to be almost 68 percent of the total.

Recreational water uses have been summarized by major areas as follows:

upper willamette basin

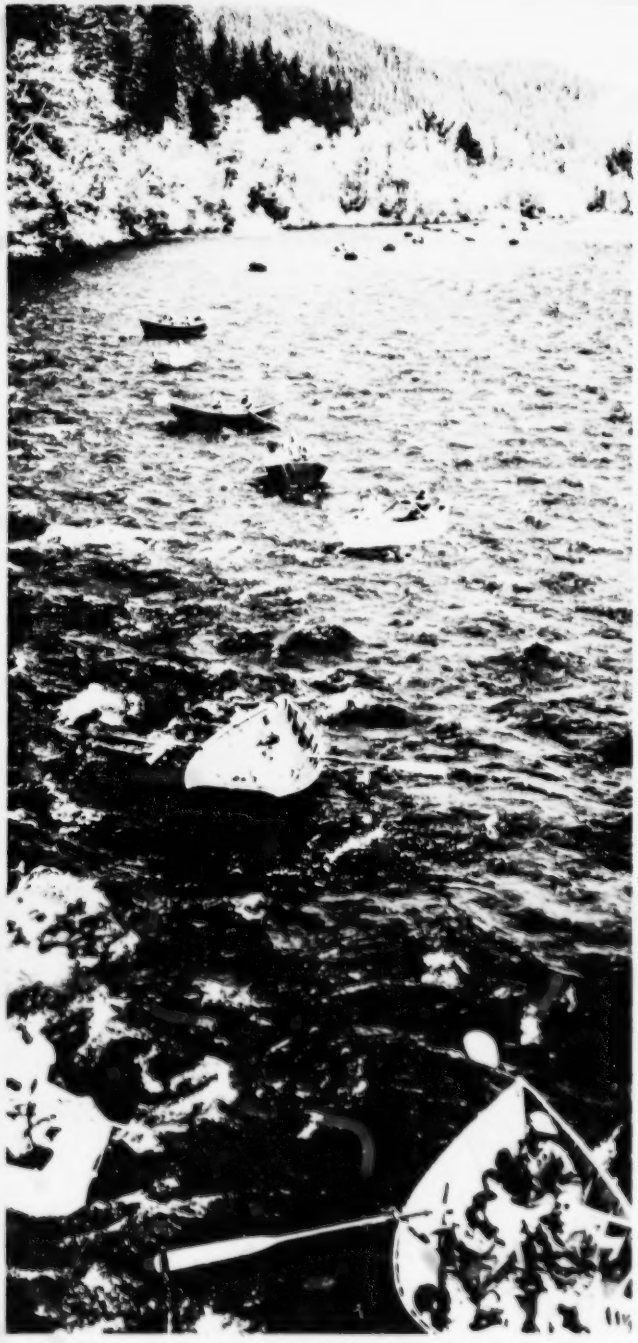
Water-oriented recreation facilities are abundant and the relative use of water recreation facilities is higher in the upper basin than in any other non-coastal portion of Oregon. Primary attractions are McKenzie River, six large reservoirs, and the Willamette National Forest.

middle willamette basin

Recreational use of water is limited in some areas of the middle basin because many streams are shallow, slow-flowing, and particularly low in the summer. At some recreational areas (e.g., Champoeg State Park, Lafayette Locks, and Newberg boat landing) waters have been posted against swimming each summer during recent years. However, portions of the Santiam River, the Cascade lakes, and Detroit Reservoir provide desirable swimming conditions, and the Willamette River and Detroit Reservoir are heavily used for boating.

lower willamette basin

The population density of the Lower Willamette Basin results in heavy recreational use of the area's water bodies despite the generally low bacterial quality of the Willamette River from Oregon City to the mouth. Among the region's water bodies, the Clackamas River is a clean, attractive, swift-flowing stream which provides swimming and fishing as well as boating and water skiing behind reservoirs. The Sandy River is a recreation site that is popu-



McKenzie River boat parade

lar with Portland residents because of its proximity to the urban area. Two State parks, Dabney and Lewis and Clark, were among the highest in attendance for the entire basin.

The Willamette River receives regular use by boaters--including some water skiing--in spite of its unsightly appearance and bacterial contamination. The reach between Portland and Lake Oswego was posted against swimming and water skiing during August of 1964 due to high bacterial densities. The sluggish and turbid Tualatin River is used by swimmers at public resorts, but most of these facilities are closed to swimming during the latter part of most summers because of pollution. The Molalla River is utilized by swimmers; and Lake Oswego, an impoundment near the mouth of the Tualatin, is the site of a residential suburb valued for its recreational advantages, notably boating, swimming and water skiing.

The large body of non-resident users has an important effect on recreational trends and demands on the water resource of the Willamette Basin. According to the State Department of Planning and Development, tourism became Oregon's second largest source of income in 1961, supplanting agriculture in that position; and much of the fixed investment in the State during the past decade has been directed to the tourist industry.

An additional factor is the latent demand that is stimulated by the development of recreational facilities. As improvements or additions to the inventory of recreation sites occur, so will per capita use. High water quality and adequate flows are required if future investments in recreation facilities are to be made in the area.

Recreation development has been largely concentrated near headwater areas, distant from population centers of the valley. However, if the current trends of increased income and leisure time continue, there will be growing pressure for broader recreational use of the Willamette River itself, which is the water recreational resource nearest to the basin's populations. There are riverside park developments in most of the communities along the banks of the Willamette; most have boat launching facilities; and each has supported measures to improve the quality of local waters through waste treatment. Current plans of Willamette Basin communities include expansion of river parks at Eugene, Corvallis, Albany, Salem, and Portland.

Water quality improvement in both the middle and lower basins will be necessary to satisfy anticipated recreational demands in those portions of the basin.

Although it is not measurable in quantitative terms, the appreciation of the physical environment must be considered an important water use. In the Willamette Basin, this aspect of water use assumes keen importance. The Willamette River passes by, or through, every major community in the basin. More than a million persons, two-thirds of Oregon's population, lived in the Willamette Basin in 1960, and over half of these in a dozen communities on the banks of the Willamette. The use of water for recreation and as a scenic adjunct to dwelling sites is a significant manifestation of public appreciation of attractive water bodies. As in development of recreational facilities, there is a trend toward more complete utilization of the river in community environment. The beauty of the physical environment is being recognized locally

and nationally as important to community feeling, productivity and personal satisfaction.

IRRIGATION

Although irrigation is a major water use in the Willamette Basin--a use that is projected to increase in the next fifty years--its impact on water is only of minor significance in comparison to arid areas of the Columbia Basin. Because of the limited land area relative to the large volume of water, withdrawals for irrigation will not significantly affect water quality in the Willamette River Basin.

The most significant water quality requirement for irrigation is mineral quality; and the mineral content of the Willamette and its tributaries is low enough to present no problems under present or projected waste loadings and flow conditions. In 1964, about 200,000 acres were being irrigated; by 1985, irrigated land is projected to be about 350,000 acres; and by 2010, irrigated land may be as high as 750,000 acres. Based on the 1964 crop distribution, the gross water diverted for irrigation was 2.56 acre-feet per acre. Applying this factor, the total water diverted for irrigation in the Willamette Basin may be estimated as follows: 1960-512,000 acre-feet; 1985-896,000 acre-feet; and 2010-1,920,000 acre-feet. The impact of irrigation return flows on water quality is not expected to be significant in most areas of the basin.

NAVIGATION

Navigation has little effect on the quality of the Willamette when all vessels meet present sanitation requirements. Quality requirements for navigation are insignificant, except that bacterial contamination can impose health hazards to navigation personnel. Accidental spills and bilge pumping are controlled by the U. S. Coast Guard. The only requirement for navigation results from the deposition of silt and sand which necessitates continuous dredging to keep the channel open.

Barge traffic between Portland and the Middle Willamette connects riverside industrial plants with downstream shipping facilities.

The river is intensively used for transporting logs in rafts to mills. The pollutional effects of this practice cannot be fully quantified but are not considered to be great.

The navigational use of the Willamette is expected to expand in the future with improvements in the channel and harbor facilities.

HYDROELECTRIC POWER

As noted in the discussion of the water resource, a number of hydroelectric power installations are constructed on the main stem and tributaries of the Willamette River. While power production is not considered a depletion of the water resource, the structures often affect the quality of the stream. Other than the quality effects of impoundments (which will be discussed in a later chapter), the operation of turbines to meet integrated power system loads causes irregularities in streamflow. Siltation results from construction activities and unstable slopes created by changing pool levels and interferes with downstream recreation and fish habitat. The power pooling schedules in the Pacific Northwest call for water resource storage during summer for power production during the fall. Thus, water stored at these dams for power purposes is largely unavailable for supplemental water flow regulation during the critical summer months.

Water Quality Objectives

Water quality objectives, as they are stated in this report, refer to goals which are desirable for the purpose of serving an appropriate use. Because they are use-directed, these objectives do not have an unvarying application. Because they represent desirable conditions rather than universally attainable goals, they will not serve as final targets for action--natural conditions and lack of technological tools would make it impossible to insure that *all* surface waters of the Willamette River Basin could be made to meet *all* of these objectives.

These objectives should be understood as desirable goals toward which a water quality program may be directed at this time. Where effective control techniques may be brought to bear--as with dissolved oxygen and biochemical oxygen demand--the objectives serve to focus action which can be expected to result in attainment. Control techniques for bacteria and temperature are less effective, but available. At worst, treatment prior to use in water supplies can be accepted; at best, disinfection of wastes can provide considerable control of bacteria in watercourses, and reservoir design and operation can often provide a worthwhile level of temperature control. Control of turbidity and concentrations of toxic materials may at this time be achieved only to a very limited extent. What is necessary in their regard is application of well considered operating practices that do not contribute to uncontrollable background presences of either natural or economic origin. In the case of toxic materials, it is essential that no direct discharge of such materials to a water body occur. Dissolved solids are a largely natural phenomenon that is not highly controllable. Limitation of irrigation and use of efficient irrigation practices may provide some moderate measure of control; but for the most part, dilution with waters having a lower content of total dissolved solids is the only feasible manner of improving this particular water quality parameter.

SUMMARY OF WATER QUALITY OBJECTIVES

Parameter	USE		
	Fishery	Water Supply	Recreation
Dissolved oxygen	Saturation is desirable minimum concentrations: Salmonid migration 5 mg l Salmonid rearing 7 mg l Salmonid spawning saturation	Saturation is desirable-divergence indicates presence of undesirable materials	5 mg l-as indicator of acceptable water quality in other respects
Bacteria	Not applicable-except as indicator of waste presence	Less than 2000 MPN 100 ml average	Less than 1000 MPN 100 ml average
Hydrogen ion concentration (pH)	6.5 to 8.5	6.5 to 8.5	6.5 to 8.5
Biochemical oxygen demand	Not applicable-except as indicator of DO deficiency or presence of undesirable wastes	Less than 3 mg l, average should not exceed 1.5 mg l	Not applicable-except as indicator of presence of undesirable wastes
Turbidity	Not applicable-except for recreational fishing--siltation intolerable on spawning beds	Low enough for effective disinfection-desirably less than 5 J.T.U.	Less than 25 J.T.U.
Temperature	Salmonid migration 45-50° (F) Salmonid rearing 50-65° (F) Salmonid spawning 45-55° (F)	Ideally, less than 50° (F)-less than 60° (F) is acceptable	Not applicable (within natural ranges)
Dissolved solids	Not applicable-except for toxicity of heavy metals	Less than 500 ppm	Not applicable
Toxic materials	As low as possible	As low as possible	As low as possible

Objectives are not presented for all of the uses which occur in the Willamette Basin. Because the major uses--the fishery, water supply, and recreation--all have extremely rigorous water quality requirements, it is assumed that a pollution control program that is directed to serving these needs will more than meet the requirements for other uses. The objectives which are presented adhere closely to those proposed for adoption by Pacific Northwest States at the 1966 spring meeting of the Pacific Northwest Pollution Control Council.

Dissolved oxygen is the over-riding need for fishery purposes. Because of the very narrow environmental tolerances of salmonid fish, a dissolved oxygen level very near saturation is essential for spawning, and protracted depressions of dissolved oxygen below 5 mg l are

believed to inhibit migration. A dissolved oxygen concentration of at least 7 mg l is considered the prerequisite for maintaining a suitable environment for trout and juvenile salmon. Hardier warm-water game fish, however, may subsist satisfactorily in waters with a dissolved oxygen content of 5 mg l. Because dissolved oxygen levels that vary from saturation indicate the presence of polluting organic substances, water supplies should be taken from sources having a dissolved oxygen level near saturation, and waters used for recreational purposes should have a dissolved oxygen concentration of at least 5 mg l.

Bacterial contamination is commonly measured by occurrence of coliform bacteria--organisms common to the intestinal tract of warm-blooded animals--which serve to indicate the level of presence of a possible source of disease. There is no hard and fast correlation between numbers of coliform organisms and probability of disease, no threshold of safety resting on sound epidemiological experience. But a relationship is known to exist. It is the practice then, of public health agencies to establish somewhat arbitrary standards for acceptable bacterial concentrations in waters utilized for domestic supply and recreation. The suggested levels for Pacific Northwest States are an average coliform concentration below 2,000 MPN in water which may be used for water supply purposes, where complete treatment is provided, and 1,000 MPN for waters used for water-contact recreation. Bacterial objectives do not apply to fish, except that high concentrations usually indicate the presence of related wastes that may have an effect on dissolved oxygen.

Hydrogen ion concentration (pH) may affect uses in a subtle fashion. Water with low pH may be corrosive, is often associated with disagreeable tastes and odors. A high pH is usually associated with hardness and stimulates growth of algae and water weeds which interfere with water intake mechanisms and affect taste. Salmon do not thrive under pH conditions much beyond the range of 6.5 to 8.5, though some resident species can flourish outside of that range.

Biochemical oxygen demand has little direct effect on either the fishery or recreational use of water; but it does serve as an indicator of the general level of water quality. High biochemical oxygen demand concentrations normally result in low dissolved oxygen levels and often accompany undesirable bacterial concentrations. For use as a water supply, water with biochemical oxygen demand concentrations exceeding 3 mg/l is considered very undesirable; an average concentration below 1.5 mg l is considered suitable for water supplies.

Turbidity levels in water supplies should be held to a minimum for aesthetic reasons. Health considerations also apply to turbidity in water supplies; it is generally considered that a level above 5 Jackson Turbidity Units (JTU) precludes effective disinfection. For recreational use, including recreational fishing, the loss of perception that occurs above 25 JTU is undesirable. In the case of water-contact sports and boating, obscured vision may lead to accidents. Similarly, lack of visibility makes the sport fisherman's gear ineffective. While turbidity's direct inhibition of the fishery is limited to sport fishing, the siltation that often causes turbidity can be disastrous to fish production. Otherwise suitable spawning gravel will not produce fish when silted over. Eggs are smothered, and production becomes impossible.

Temperature is critical to salmonid fish and of great importance to water supply. Migration of anadromous fish requires a temperature range of 45 to 70 degrees (F); rearing of both trout and salmon occurs in a somewhat narrower temperature range, 50 to 65 degrees; and spawning requirements are very narrow, with temperatures beyond the range of 45 to 55 degrees destroying fish production if sustained beyond a very limited period of time. Cool water is also desirable for water supplies, both for aesthetic reasons and for efficiency in cooling applications. Temperature not exceeding 50 degrees is considered desirable, with 60 degrees representing the upper temperature limit for acceptable Pacific Northwest water supplies.

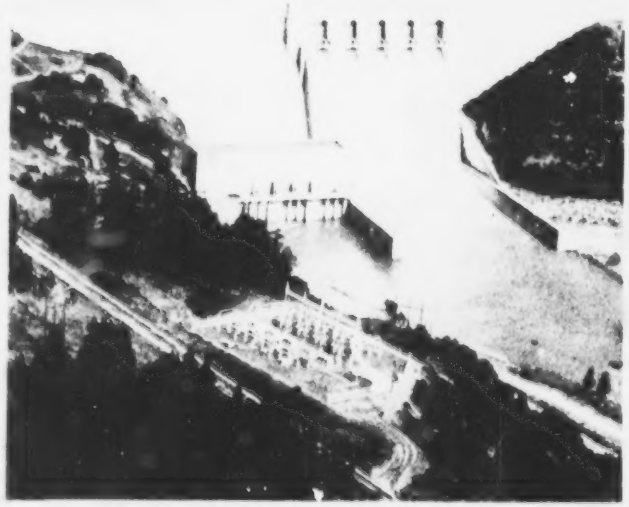
Dissolved solids concentrations are delimited by the Public Health Service drinking water standard of 500 parts per million. Total dissolved solids are of little significance in assessing water quality in the Willamette Basin, since concentrations in its surface waters are customarily only about a tenth of the recommended maximum.

Toxic materials--which cover a wide spectrum, from naturally occurring heavy metals, to radioactive materials, to complex insecticidal and herbicidal compounds--should be viewed not in terms of tolerances but rather in terms of maintaining the most complete possible degree of their absence in waters. Except for occasional instances of arsenic in groundwater, no known toxics occur naturally in Willamette Basin waters. The quality objective, then, must be expressed to be the highest possible degree of control against occurrence of such materials in water.

CHAPTER FOUR

MUNICIPAL & INDUSTRIAL WASTES AND OTHER FACTORS AFFECTING

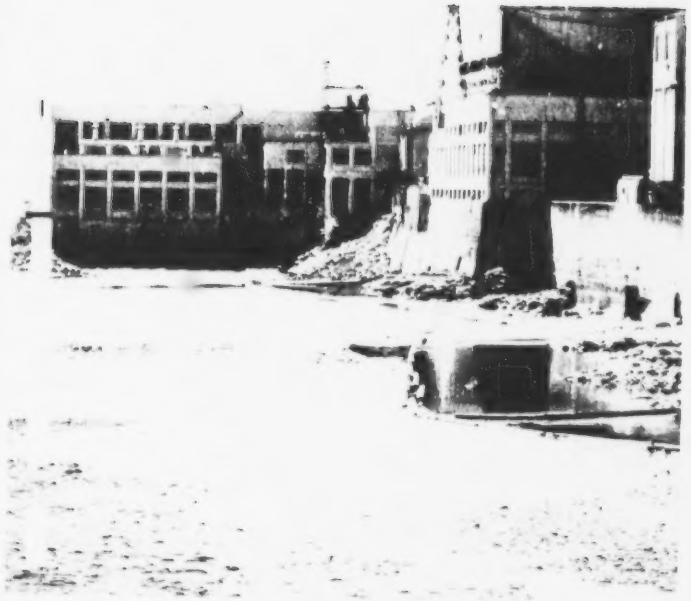
WATER QUALITY



Introduction

Water quality levels result from the interaction of many elements. Chief among these are the conditions of the natural environment. Man's activities also modify water quality--waste disposal, land use practices, and the operation of impoundments being particularly significant in this regard.

Waste discharges from municipalities and industries have the most significant effect on water quality in the Willamette Basin. These wastes include organic material, bacteria, suspended solids, and nutrients--each of which caused deterioration of water quality. Oxidizable wastes are responsible for the depression of dissolved oxygen; municipal sewage results in bacterial contamina-



tion; suspended solids (particularly pulp and paper fibers--when settled out--cause unsightly oxygen-demanding sludge beds; and nutrients stimulate slime and algal growths.

Biochemical Oxygen Demand--Throughout the discussion of municipal and industrial wastes, the strength of organic wastes is measured in terms of the biochemical oxygen demand (BOD). The BOD is a measure of the oxygen required to stabilize decomposable organic matter. One pound of BOD is equal to the waste produced by about six people and organic industrial loads are expressed in terms of population equivalents (PE).

Municipal Wastes--Municipal sewage is defined as the water-carried waste from residential, public, commercial, and minor industrial sources discharged into a collection system for transport to a central treatment and or discharge point. A factor of 25 percent has been added to the estimated population connected to each system in order to account for additional waste from modern households and the organic waste from commercial and minor industrial sources.

Industrial Wastes--For discussion purposes in this chapter, industrial wastes are those spent process waters associated with industrial operations which are discharged separately and not in combination with municipal wastes.

Adequate Treatment--Adequate treatment for municipal and industrial organic wastes in the Willamette Basin is defined as efficient removal and separate digestion of settleable and floating solids and biological treatment to effect *at least* 85 percent reduction of BOD. In addition, sanitary wastes should be effectively disinfected with facilities designed for disinfection and providing sufficient contact with the disinfecting agent before discharge--such as that provided by addition of sufficient chlorine to provide residual of 0.5 ppm after fifteen minutes or 0.2 ppm after thirty minutes. Higher degrees of treatment for specific waste sources may be required, depending upon the size and nature of the waste load and receiving stream.

Waste Loads

At the present time, municipalities and industries in the basin produce wastes equivalent to those from a population of about six million persons (exclusive of the city of Portland which discharges treated wastes to the Columbia River). Municipal wastes total 435,000 PE and industrial wastes equal those from an additional population of about 5,500,000 people. Of the total wastes generated in the basin, 75 percent if from the pulp and paper industry, 11 percent from the food-processing industry, 7 percent from municipal sources and 1 percent from the forest products industries. The remaining 3 percent is from other miscellaneous industries within the basin and uncontrolled discharges to Portland harbor through numerous private and storm sewers.

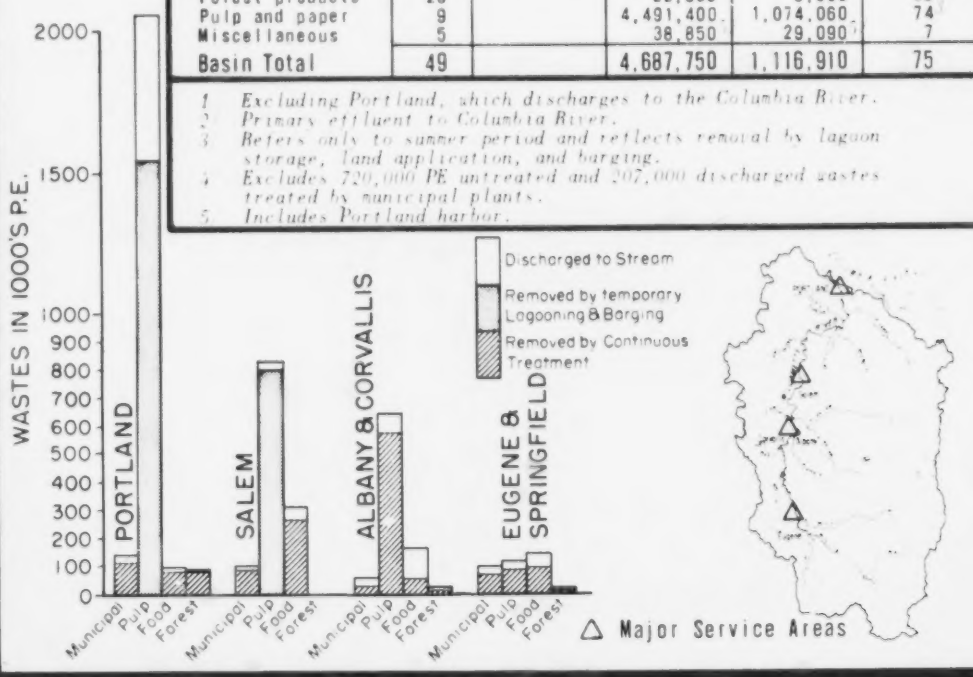
During the critical summer period, treatment and other means of industrial waste reduction decrease total waste strength by about 75 percent to 1,500,000 PE before discharge. Pulp and paper waste reduction represents summer conditions when many mills are temporarily barging wastes out of the Willamette Basin to the Columbia River, holding in storage lagoons, or applying wastes to land. During the remainder of the year, these wastes are discharged directly to the watercourse (along with wastes then being produced) with little or no reduction in strength.

The map showing present total and discharged waste loads at major service areas indicates the distribution of wastes by category throughout the basin. Pulp and paper wastes are by far the largest category, and inadequate treatment of these wastes is particularly notable in the Salem, Portland, and Newberg service areas. The second largest contributor is the food-processing industry, particularly significant in the Salem,

MUNICIPAL AND INDUSTRIAL WASTES
WILLAMETTE RIVER BASIN

	Number of Plants	Population Served	Population Equivalents Untreated	Population Equivalents Discharged	Removal Efficiency
PRESENT MUNICIPAL WASTE TREATMENT:					
Secondary	66	323,125	1,026,720	229,550	78
Primary[1]	8	36,350	140,950	96,880	32
Lagoon	8	5,390	5,410	940	83
Other	8	1,000	350	350	0
Subtotal	90	366,715	1,174,930	328,450	72
Portland (primary)	1	370,000	385,000	[2]	
Basin Total	91	736,715	1,559,930	328,450	79
PRESENT INDUSTRIAL WASTE TREATMENT:					
Food products	13		134,550	4,100[4]	97
Forest products	20		22,950	9,690	58
Pulp and paper	9		4,491,400	1,074,060[3]	74
Miscellaneous	5		38,850	29,090[3]	7
Basin Total	49		4,687,750	1,116,910	75

1. *Excluding Portland, which discharges to the Columbia River.*
2. *Primary effluent to Columbia River.*
3. *Refers only to summer period and reflects removal by lagoon storage, land application, and barging.*
4. *Excludes 720,000 PE untreated and 207,000 discharged wastes treated by municipal plants.*
5. *Includes Portland harbor.*



Waste production is concentrated in four areas. With the exception of the pulp and paper industry, which relies partly on storage or transportation of wastes, a high level of waste reduction is achieved by most waste sources.

Albany-Corvallis and Eugene-Springfield service areas.

MUNICIPAL WASTE TREATMENT

Of 91 municipal waste sources in the basin, 66 presently receive secondary treatment; however, eight of these facilities require enlargement or replacement to handle present loads. Six of the eight primary treatment facilities must convert to secondary treatment in order to meet minimum OSSA treatment requirements, and the other two are expected to connect to existing systems. The city of Portland discharges its wastes to the Columbia River after primary treatment; the OSSA has directed the city of Portland to intercept 28,000 PE of raw waste which is presently discharged to Portland harbor.

New secondary treatment facilities now in operation in the Eugene-Springfield, Albany-Corvallis, and Salem service areas are designed to treat not only municipal sewage but also the wastes from many of the large fruit- and vegetable-processing plants and small industries located in the area. During the July-September food-processing season, about 75 percent of the total waste load to these municipal plants is contributed by these industries.

For the Willamette Basin, excluding Portland and Gresham, accumulative per capita investment for municipal waste treatment and collection during the period from 1947 to 1962 was $124.43, of which about half was for treatment. Since Portland and Gresham discharge to the Columbia River, investment for primary treatment in these areas has been considerably lower. Of the total per capita investment of $58.23 for sewage collection and treatment, about 90 percent has been spent for interception.

The Federal program of construction grants has added stimulus to the installation of municipal treatment facilities in the basin. In the first eight years of this program (1956–64), grants representing a total Federal investment of $4.7 millions were issued. These grants constituted 22 percent of the total eligible cost of the projects.

IMMEDIATE MUNICIPAL WASTE TREATMENT NEEDS--JULY 1965

COMMUNITY	TREATMENT NEEDS	STATUS
Albany	Secondary Treatment	Preliminary plan
Corvallis	Secondary Treatment	Under construction
Cottage Grove	Secondary Treatment	Preliminary plan
Dallas	Plant Enlargement	Preliminary plan
Eugene	Plant Enlargement	Under construction
Fanno Creek San. Dist.	Plant Enlargement	Final plan
Harrisburg	Secondary Treatment	Preliminary plan
Hillsboro Plant No. 1	Plant Replacement	Preliminary plan
Independence	Secondary Treatment	Final plan
Junction City	Secondary Treatment	Preliminary plan
Mt. Angel	Plant Enlargement	No plans
McMinnville	Plant Enlargement	No plans
Monroe	Primary and Secondary Treatment	Preliminary plan
Oakridge	Secondary Treatment	Preliminary plan
Portland;	Interception and Treatment of 28,000 PE raw waste discharge in Portland harbor	Final plan
Sweet Home	Plant Enlargement	Final plan

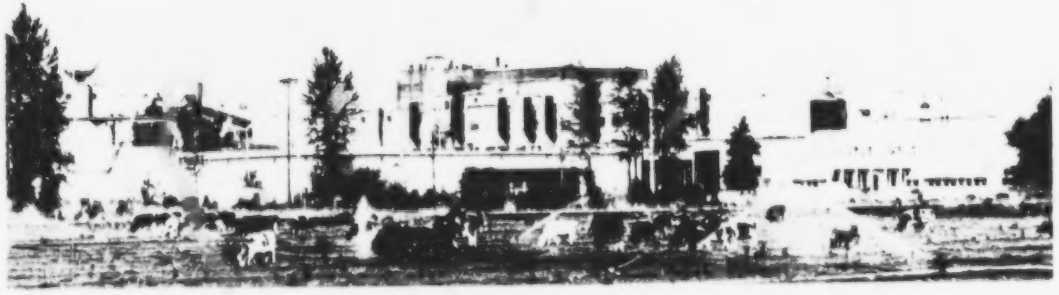
INDUSTRIAL WASTE TREATMENT

Of the total wastes produced in the basin, 90 percent results from industrial sources. Eighty percent of the industrial component is contributed by the pulp and paper industry. Fifteen percent (largely food processing) is discharged to municipal treatment facilities. Five percent is contributed by the remainder of food processing, forest products, and miscellaneous industries.

pulp and paper

Pulp and paper wastes comprise about 75 percent of the organic waste load discharged to Willamette Basin streams. The waste treatment and control measures employed have been only partially success-

Cattle grazing in pasture spray irrigated with evaporator condensate. Irrigation during summer low flow periods is an effective means of keeping this high BOD wastewater out of the Willamette. (Weyerhaeuser photo)



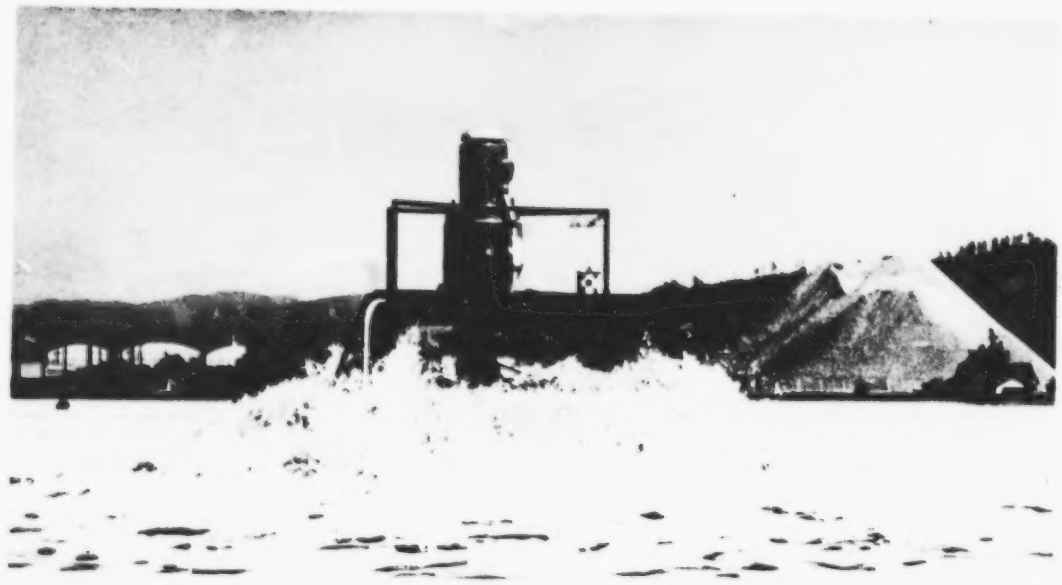
ful in preventing unsatisfactory water quality, and pollution problems exist below each mill.

Because of their great effect on water quality, it is evident that the massive organic waste loadings that result from the manufacture of pulp and paper should also be given a high level of treatment. This is not presently the case. Those mills which, by virtue of process efficiencies, have the lowest waste to product ratio have generally provided some measure of post manufacturing treatment. The relatively inefficient (in terms of waste to product ratio) sulfite pulp mills, however, have generally avoided waste treatment, substituting waste storage or transmission for waste reduction.

Existing waste treatment measures applied in the pulping and papermaking industry indicate that significant reductions in waste strengths are possible through application of a series of processes which have generally been designed into newer pulp and paper plants built in the United States. The procedures include: 1) reduction of strength of pulping liquors through evaporation and burning, which is an integral part of sulfate pulping and some types of sulfite pulping where it is employed for the recovery of cooking chemicals, 2) primary sedimentation, and 3) secondary treatment. The average strength of waste discharges which might be anticipated with this series of procedures is well below that which is computed for Willamette Basin plants.

The Weyerhaeuser Company operates a 1,150-ton-per-day unbleached sulphate pulp mill on the McKenzie River at Springfield. All pulp is converted to liner board. From a waste discharge standpoint, this industry has operated at a low chemical and fiber loss rate due to careful in-plant control measures, re-use of strong waste flows, and disposal by land irrigation. Present waste loads are 16,000-18,000 pounds of BOD per day. These loads represent sufficient reduction to prevent critical DO levels in the McKenzie River. However, slime and odor problems in the stream have been cause for complaint.

The industry is presently planning the installation of both primary and secondary treatment measures sufficient to reduce the waste loading to 4,000 pounds



BOD per day or just under 4 pounds of BOD per ton of production.

The Crown Zellerbach Corporation operates a 110-ton-per-day ammonia-base sulphite pulp mill at Lebanon on the Santiam River. Production is converted locally to corrugating medium and shell paper. During the low flow periods, all collectible liquor solids from the blow pits are evaporated and burned or dried. Present BOD loads from the mill are 8,000–10,000 pounds per day during low streamflow.

The OSSA has requested primary treatment and reduction of BOD loadings to a level which will prevent growth of any objectionable slime in the Santiam River. The industry is presently completing construction of short-term lagooning facilities for primary treatment. An extremely high degree of secondary treatment will be necessary to reduce the present oxygen-demand loading to the levels required by the OSSA.

The Western Kraft Corporation operates a 450-ton-per-day unbleached kraft pulp mill at Albany. Liner board and bag paper are also produced. Normal kraft recovery operations are practiced. Present waste loads, discharged to the main stem Willamette River, are reported to be 8,000–12,000 pounds of BOD per day. The mill will soon expand to 500-ton-per-day production, with capabilities for 650 tons per day. If the presently reported waste reduction to 26 pounds of BOD per ton is maintained after expansion, stream loads would be about 13,000 pounds of BOD per day. The industry has recently completed two earthen ponds to provide, in series, 24-hour detention time for settleable solids reduction.

It would appear that primary settling and projected BOD loading would result in waste discharges well within the assimilative capacity of the stream from a dissolved oxygen standpoint. Should objectionable slime conditions or evidence of biological toxicity develop, adequate land now owned by the industry will permit installation of more advanced treat-

The Boise Cascade Corporation operates an ammonium base sulphite pulp mill and paper mill at Salem. Pulp production is about 185 tons per day. The mill has a 150 mg lagoon for storage of spent liquor during low streamflow seasons. Both normal plant wastes and stored liquor are discharged to the stream during higher flows—a procedure followed by all sulphite pulp mills in the basin employing lagoon storage facilities. Release of stored wastes in addition to normal plant wastes during the six winter months produces tremendous quantities of slime which continually move in suspension. These slimes settle to the bottom in areas of less turbulent flow and add to the benthic demand on the oxygen assets of the stream during the summer months.

This mill, following the recommendations of the OSSA, is planning the installation of primary treatment facilities. Summer storage of spent liquor can only be considered a temporary measure. The conversion to a soluble-base

Process	Waste per Ton of Product	
	Expectable w Treatment lbs BOD	Willamette Basin Mills 1965 lbs BOD
Sulfite pulping	50	550 (5 sulfite mills)
Sulfate pulping	10	[illegible] (2 sulfate mills)
Groundwood pulping (bleached refiner)	35	20 (2 groundwood mills)
Papermaking	[illegible]	14 (3 paper mills)

liquor appears necessary. All pulp washings, condensates, bleach liquors and other significant sources of strong wastes should be afforded secondary treatment. Existing holding lagoons may be converted to mechanically aerated stabilization lagoons to provide 75 percent reduction of residual waste loads remaining after recovery practices.

The Publishers Paper Company operates a 175-ton-per-day calcium-base sulphite pulp mill at Newberg, producing unbleached sheet pulp. An 80 mg storage lagoon is presently available to hold waste liquor during low streamflow periods. This mill is converting to a 200-ton-per-day magnefite pulping process without recovery. In addition, a 350-ton-per-day bleached refiner groundwood mill will be built and a 380-ton-per-day newsprint mill will convert all groundwood pulp and a portion of the sulphite production.

The mill is presently planning installation of primary treatment facilities as recommended by the OSSA. The industry is also providing an additional lagoon for storage of 120 mg of spent liquor, providing a total storage capacity of about 200 mg at the mill site. Ultimate waste control and treatment needs for this mill will require recovery of spent liquor and biological oxidation of oxygen-demanding materials contained in pulp washings, condensates, and refiner groundwood effluents. Biological treatment facilities may be developed by converting planned storage lagoon facilities to mechanically aerated flow-through stabilization basins.

The Crown Zellerbach Corporation pulp and paper mill at West Linn produces 180 tons per day of calcium-base sulphite pulp, about 250 tons per day of stone and refiner groundwood pulp, and 560 tons per day of paper products. Present waste control and treatment facilities consist of a storage lagoon of about 100 mg for storage of strong spent liquor and primary facilities for separation of settleable solids. The primary tank receives nearly half of the volumetric loading from the mill and two-thirds of the settleable solids loading. The mill's technical staff is evaluating the performance of these settling facilities. Other waste sources could be intercepted, and additional settling capacity constructed.

Ultimate treatment for this industry requires reduction of BOD loading on the stream because of its effect on critical DO, slime, and sludge decomposition in Portland harbor. Installation of soluble-base pulping and recovery, or evaporation and burning of present calcium-base liquor, would provide waste load reduction for twelve months of the year. By either means, the 100 mg storage lagoon could be used as a mechanically aerated stabilization basin. Two lagoon cells

Company and Location	Year Built	Products	Tons Day*	Waste Treatment or Control	Additional Needs	Status of Improvement
Weyerhaeuser Springfield, Ore.	1949	Unbleached Kraft pulp Liner board	1 350 1 150	Kraft recovery and land irrigation	Primary settling & secondary treatment	Planning primary and secondary
Crown Zellerbach Lebanon, Ore.	1890	Ammonia sulphite pulp Corrugating and shell paper	110 110	Evaporate and burn or dry, installing settling	Primary settling secondary treatment	Planning primary
Western Kraft Albany, Ore.	1955	Unbleached Kraft pulp Liner board and bag paper	500 500	Kraft recovery primary treatment	Secondary treatment	
Boise Cascade Salem, Ore.	1923	Ammonia, bleached sulphite pulp Sulphite paper products	185 215	150 mg storage lagoon for sulphite liquor	Chemical recovery, primary settling & secondary treatment	Planning primary
Publishers Paper Newberg, Ore.	1926	Ca-base, unbleached sulphite pulp (as sheet pulp) Planned Expansion Magnefite sulphite Refiner groundwood bleached Newsprint	175 210 350 380	Storage lagoon for sulphite liquor 200 mg storage lagoon for sulphite liquor	Chemical recovery, primary settling & secondary treatment	Planning primary
Publishers Paper Oregon City, Ore.	1908	Ca & Mg base sulphite pulp Refiner and stone groundwood pulp Paper products	170 300 490	Barging sulphite liquor	Primary settling secondary treatment & chemical recovery	Planning primary and chemical recovery
Crown Zellerbach West Linn, Ore.	1888	Ca-base sulphite pulp Groundwood pulp Paper products	180 250 560	100 mg storage lagoon for sulphite liquor primary facilities	Pulp liquor recovery & secondary treatment	

[illegible]

are now employed. Some influent, effluent, and transfer problems may exist; however, these difficulties can undoubtedly be solved to permit the biological oxidation of all significant remaining oxygen demand loads generated by the industry.

Publishers Paper Company at Oregon City operates a 170-ton-per-day sulphite pulp mill, a 300-ton-per-day refiner and stone groundwood mill, and produces about 490 tons per day of paper products. This industry has converted half of its sulphite mill to the magnefite process and material to complete the conversion is on hand. Past waste control measures have consisted of barging strong collectible liquor to the Columbia River. This procedure must be discontinued by 1969 under requirements of the Lower Columbia River enforcement conference of 1965. The industry plans to continue liquor barging temporarily; however, planning is underway for base recovery, which will eliminate the need for barging and provide for recycling of valuable chemicals to the pulping process. Engineering consultants have been retained to develop plans for primary treatment of the total wastewater flow.

Ultimate waste control and treatment for this industry should include biological stabilization of pulp washings, condensates, groundwood waste streams, and other concentrated wastes presently discharged to the stream. Space for installation of any conventional secondary treatment facilities is limited since the mill is surrounded by the city or river. All possible waste-saving in-plant controls should be employed within the mill complex. Any additional need for secondary treatment for residual loads from this industry will present a challenge to the industry and its engineering consultants because of the mill location.

Food processing

Food processing wastes are seasonal in the Willamette Basin; the campaign for most of the fruits and vegetables is July through September. Although a major portion of these wastes is treated through municipal systems, an additional load of 134,000 PE is treated by separate facilities before discharge to the watercourse. Waste stabilization ponds are generally used as the treatment for fruit and vegetable processing wastes. Spray irrigation is also practiced where land is available.

Other industries

In addition to pulp and paper production and food processing, a number of other industries exist in the basin. These include forest products plants, woolen mills, dairies, and an electronics firm. Except for those along the Portland waterfront, these industries provide adequate treatment of their wastes.

FUTURE MUNICIPAL & INDUSTRIAL WASTE LOADS

Projections of municipal wastes are based on population projections for 1985 and 2010. Raw waste loads are based on the assumption that the entire urban population will be sewered by 1985. Discharge loads were computed assuming 90 percent average reduction of BOD by 1985 and 95 percent reduction of BOD by 2010.

Industrial waste projections were developed from present loadings and projected increased production in the major industrial categories. Food processing wastes are projected to double by 1985 and double again by 2010. Pulp and paper wastes were projected by applying production growth rates to present waste loads. BOD reduction of 90 and 95 percent for 1985 and 2010, respectively, was likewise assumed for these wastes.

Pulp and paper wastes are forecast to remain the predominant organic load in the future; although, as population expands, the percentage of municipal wastes is expected to increase. By 1985, the total basin wastes will be generated as follows: pulp and paper--70 percent; food processing--15 percent; and municipal--15 percent.

Pollution From Land Use

Land use practices can alter the physical environment of a river basin and affect water quality. The following waste materials are identifiable as present or potential pollutants from land use in the Willamette River Basin: sediment, minerals, nutrients, toxicants, temperature, bacteria, and organic matter. Discussion of these wastes is limited to their sources and importance to water quality.

SEDIMENT

A generalized pattern of sediment transport shows that, except for flood periods, the basin's streams are relatively low in concentrations of suspended matter. High concentrations of sediment generally occur during periods of high precipitation and snowmelt and are carried in flood flows. Depositions have to be dredged from the Portland harbor and Columbia River to maintain navigation channels, and suspended materials must be removed in water treatment for municipal and industrial use--demonstrating the economic significance of sediment. The aesthetic appearance of the stream, fish spawning grounds, and aquatic food supplies can be affected or destroyed by sediment.

Average annual sediment production in the Willamette, as measured in Portland

harbor in 1963, was 4.5 million tons. Peak concentrations were recorded during the extreme floods of December 1964.

Santiam River	1,040 ppm
Willamette River at Salem	892 ppm
Willamette River at Wilsonville	1,080 ppm
Molalla River near Canby	1,930 ppm
Clackamas River near Clackamas	1,820 ppm
Willamette River at Portland	2,050 ppm

The sediment discharge of the Willamette River at Portland in the period December 21–31, 1964, was 6,570,000 tons—about one and one-half times the sediment transport for the entire 1963 water year.[1]

The lands most subject to erosion are forest lands on steeper slopes which are exposed to high rainfall and snowmelt. These lands comprise 66 percent of the basin, and some of the soils are of geologic origin susceptible to erosion. Therefore, it is imperative that the proper management practices be followed in making changes in the forest environment.

Of the present annual timber cut of 3,000 million board feet, about 60 percent is from privately owned lands and about 40 percent from public lands. These ratios will change to about 50 percent each by 2010, with about 2,800 million board feet being logged.

Proper logging practices, careful planning for road construction and maintenance of vegetative cover can greatly reduce sediment production from forest lands. It is estimated that 1.5 million acres of forest land (58 percent of the basin) is amenable to land management practices to reduce rapid runoff and erosion. An inventory of soil types must be available before detailed management practices can be outlined.

[1] *B. C. Williams and H. H. Stevens, Jr., U. S. Geological Survey, at Sediment and Erosion Meeting, April, 1965, Water Supply and Pollution Control Subcommittee, CBAC.*

MAXIMUM SEDIMENT CONCENTRATIONS

	Concentration (ppm)
Upper Basin	
Coast Fk. Willamette R. nr. Landon	400
Coast Fk. Willamette R. below Cottage Grove Dam	260
Row R. nr. Star	330
Row R. below Dorena Dam	130
Middle Fk. Willamette R.	380
Willamette R. at Springfield	350
McKenzie R.	240
Long Tom R. at Elmira	126
Long Tom R. below Fern Ridge Dam	299
Coyote Crk.	156
Middle Basin	
Marys R.	500
Calapooia R.	340
So. Santiam R.	370
No. Santiam R.	250
Santiam R.	503
Luckiamute R.	410
Willamette R. at Salem	400
So. Yamhill R.	800
Pudding R.	315
Molalla R.	560
Lower Basin	
Tualatin R.	390

Elliott Flaxman, SCS, Proceedings, Fifth Symposium PNW, 1959, WSPC, USPHS.

Crop lands (presently 19 percent of the basin) must be managed to prevent rilling, gullying, and sheet erosion of bare ground during high winter rainfall and runoff. The U. S. Department of Agriculture estimates that 1,386,000 of the 2,800,000 arable acres in the basin are conducive to land treatment measures for erosion control.

The lands most subject to erosion are forest lands on steeper slopes which are exposed to high rainfall and snowmelt. These lands comprise 66 percent of the basin, and some of the soils are of geologic origin susceptible to erosion. Therefore, it is imperative that proper management practices be followed in making changes in the forest environment.

The sprinkler method, which uses less water than other methods, is used on 98 percent of the 194,000 irrigated acres in the Willamette Basin; proper tending minimizes surface runoff, thereby reducing the production of sediment in streams. Projected irrigation of 355,000 acres in 1985 and 750,000 acres by 2010 is expected to be principally by sprinkler irrigation and should not contribute significantly in itself to the sediment problem.

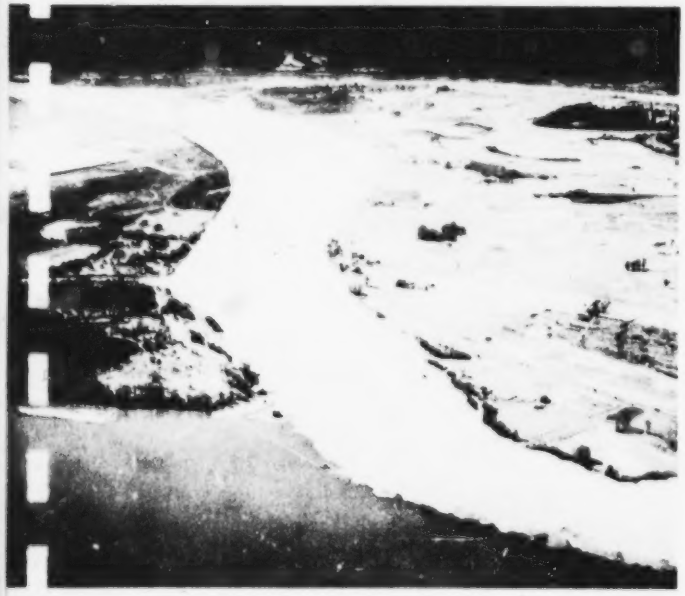
The major single source of sediment is bank cutting caused by flood flows both in descent from the steeper forest slopes and in stream and river channels of the valley floor. Land management practices alone cannot control this erosion and must be supplemented by flood control and channel protection. Flood plain zoning to allow uncontrolled flood waters to spread and dissipate reduces crest height and velocity to decrease bank cutting.

The Soil Conservation Service has a program (P. L. 566) to protect watersheds and control floods with small watershed storage projects and land treatment programs. Its efforts supplement the larger

SEDIMENT SOURCES				
	Unit Rate tons sq.mi.	Square Miles	Tons	Percent Contribution
Bank-cutting and channel scour			2,200,000[a]	40
Agriculture	400	2,800	1,120,000	21
Forest, logged	40,000	25[b]	920,000	17
Forest, good cover	20	7,950	160,000	3
Other (urban and highway construction, gravel operations)	40,000	26.5[c]	1,060,000	19
TOTAL			5,460,000	100

a. Fifty percent of the estimated annual sediment load at Portland for 1963.
b. 7.8 square miles logged annually, multiplied by three years effective sediment yield before re-vegetation to equal equivalent square miles.
c. Two percent annual construction growth of the 1,325 square miles of "Other" leaving the disturbed ground unprotected for one year.

Characteristically muddied by the swift flows and surface runoff caused by heavy winter rains, the entering waters of the Willamette contrast sharply with the receiving Columbia.



flood control projects of the Corps of Engineers and Bureau of Reclamation.

Stripping of vegetative cover and massive disturbance of soil in construction activities for urban-suburban structures and highways contribute large quantities of sediment during runoff periods. Construction activities produce 25,000–50,000 tons per square mile, as compared to 20–500 tons contributed from normal forest or crop lands, as reported in studies in Maryland and Virginia.[1]

Time of occurrence of sediment production is extremely important. Because it can settle out, sediment has a greater impact on fish spawning areas during reduced streamflow and velocity than in periods of greater runoff, streamflow and velocity. Also, in periods of low discharge, the stream carries virtually no suspended matter, and any substantial addition is readily apparent visually.

[1] *Interstate Commission on the Potomac River Basin. "A Program for Sediment Control in the Washington Metropolitan Region". Technical Bulletin 1963-1.*

MINERALS

High rainfall and runoff in the Willamette Basin have historically dissolved and removed soluble minerals so that most streams have concentrations of less than 50 ppm dissolved solids. Any accumulations of dissolved solids that might result from evapotranspiration in forests or irrigated and other agricultural lands are seasonally removed during the winter rains when runoff is greatest and the concentration of dissolved solids in the streams is the least.

Even with a future annual mineral load of 3 million tons (165 percent of the present load), future mineral loadings from population, irrigated lands, and manufacturing would result in a mean annual concentration of only about 85 ppm in the Willamette at Portland harbor. This concentration would have little effect on water uses.

Due to the high precipitation and prolonged leaching of the soil, many of the basin's waters have pH values below 7.0, a condition which brings more iron and silica into solution especially in some groundwaters. Consequently, the groundwater mineral content is less suitable than surface water for municipal and industrial use.

NUTRIENTS

The chemical constituents termed nutrients stimulate aquatic growths. Slimes, algal forms, and other growths create unsightly nuisance conditions and obnoxious taste and odor problems. The exact nature of the nutrient balance which will produce algal blooms is not known; however, nitrogen and phosphorus appear to be significant factors in stimulating excessive growths.

The total nitrogen yielded to the Wil-

lamette River as measured at Portland harbor is about 130,000 tons of nitrates annually. Of this total, it is estimated that 11 percent is contributed by people, 12 percent by agriculture, 5 percent from cattle, 5 percent from rain, and 67 percent from unknown sources. The large percentage of nitrogen attributed to unknown sources testifies to its elusory nature and indeterminant relation to the stimulation of algal growths.

Phosphate is of equal significance, even though the quantity is somewhat smaller. About 2,500 tons of phosphate reaches the watercourse. Two-thirds is contributed from fertilizers, and about one-third emanates from human wastes. The quantities of phosphorus and nitrogen reaching the basin's streams from forest and agricultural lands or other sources are quite small, except during periods of winter runoff when temperature is not amenable to optimum algal or aquatic growth.

TOXICS

Most of the substances that are toxic to the aquatic habitat are man made or caused. These include organic and inorganic pesticides, certain minerals, and petroleum products washed into streams from highways or industrial areas. None of these toxicants is considered to be a problem in the Willamette Basin.

Although use of pesticides is extensive in the Willamette Basin, there is little evidence that noteworthy concentrations reach the streams. Soil is a good filter media, so that careful application of the 1,600 tons of herbicides, 8,000 tons of fungicides, and 3,300 tons of insecticides used annually can prevent damaging concentrations from reaching the waterways. The use of pesticides should, therefore, be closely regulated by control agencies.

TEMPERATURE

Logging practices of clear-cutting small scattered tracts will cause temporary increases of one to eight degrees (F) in stream temperatures of local watersheds until sufficient vegetative cover provides ground shade. However, these increases have little effect on temperatures of major streams in the basin.

BACTERIA AND ORGANIC MATTER

Animal feedlots located adjacent to streams or animal wastes flushed into Willamette streams not only contribute a high bacterial concentration to the streams but also exert a biochemical oxygen demand. This becomes particularly significant in times of low flow.

Estimates of potential fecal streptococci from animal sources in the Willamette Basin for 1959 were over 78 times that from human sources. Assuming a 90 percent reduction to land disposal, the magnitude of the animal sources is almost eight times that of human sources before treatment.

The oxygen demand of the waste from the 223,000 livestock in the basin would be about equal to that of the total population of the Basin. What amount of these wastes reaches the waterways is unknown. However, these relationships point out the necessity of proper handling and management of domestic animal wastes to prevent them from reaching the streams.

Impact of Impoundments

When a free-flowing stream is impounded, the modification of its physical and chemical properties and biological populations results in changes in the quality of the water. Although many of these changes might improve water quality downstream, specific quality parameters within the reservoir are often adversely affected. These effects depend upon surface area, depth, and detention time. The changes in quality that occur during storage in a given environment are considered here in two broad categories--beneficial aspects and detrimental aspects.

BENEFICIAL ASPECTS

The greatly reduced velocity of flow through a reservoir section of a stream has a direct effect on the quality below the impoundment. Suspended material transported from drainage areas above the dam settle out during the period of reduced velocity and effects a reduction of oxygen-consuming material and turbidity below the structure. Bacterial quality is also improved by the reduction of velocities through reservoirs; increased time of travel permits the natural die-away of bacteria. Reductions of 90 percent in coliform concentrations can be obtained even in small reservoirs, and up to 98 percent reduction has been observed in reservoirs providing long periods of retention.

Because of the temperature stratification in larger reservoirs, cool water releases from low-level outlets during periods of high summer temperatures will lower water temperature below the impoundment. Such reductions are usually beneficial to downstream water quality because of lower stream temperatures.

DETRIMENTAL ASPECTS

The same hydraulic and physical characteristics which benefit downstream water quality can also create adverse conditions within the impoundment. Thermal stratification in deep reservoirs results in the isolation of surface and bottom layers and prevents reaeration of lower levels. As organics settle out and decompose and as biological organisms

decay, dissolved oxygen concentrations are depleted in the bottom layers. Releases from low-level outlets during periods of thermal stratification can therefore be detrimental to downstream oxygen concentrations.

The stimulation of algal growth is a second adverse effect of impoundments. Warm surface temperatures and increased depth of light penetration through the clear waters of reservoirs contribute to prolific algal growth, particularly when abundant quantities of nutrients are present--such as nitrogen and phosphorus found in domestic and industrial wastes and land drainage. These biological organisms create nuisance conditions and affect the DO concentrations through their photosynthetic activity and decomposition. An over-abundant nutrient supply will eventually lead to long-term stimulation of the algal population of the reservoir and result in the "aging" of the lake. Accumulation of large quantities of organic solids on the reservoir bottom can also lead to anaerobic decomposition with the production of hydrogen sulfide and methane gases.

Design of reservoirs may also affect water quality. Fixed outlets limit withdrawals to one depth and the quality characteristics at that depth, while multiple outlets provide more flexibility for controlling water quality.

WILLAMETTE BASIN RESERVOIRS

The effect of impoundments on water quality in the Willamette Basin is not considered to be a major problem today. Willamette dams are relatively new, and changes that may be occurring are still slight enough that they are difficult to detect. Because there are presently no major waste sources entering the streams above major Willamette reservoirs, there have been few complaints of poor water quality in the reservoirs except for taste and odor problems. There are, however, potential effects which must be considered in order to prevent serious problems in the future.

Willamette system reservoirs may be classified as "intermediate" or "shallow" according to their depth and vertical temperature structure. The intermediate reservoirs include Detroit, Cougar, Lookout Point, and Hills Creek; these reservoirs undergo thermal stratification during certain times of the year and could potentially have a pronounced effect on the water quality. The rest of the impoundments are considered "shallow", and there is very little temperature gradient.

Shallow reservoirs which could have future problems include Dorena, Cottage Grove, and Fern Ridge. Because these reservoirs are located on river reaches upstream from which there are no dams to retain organic material, they receive the full load of nutrient and siltation inflow.

RESEARCH ON DETROIT RESERVOIR

In cooperation with the Corps of Engineers, the FWPCA has carried out a series of monthly water quality investigations in Detroit Reservoir since 1964 to gather background information on a relatively good water-quality, intermediate reservoir. Parameters measured were: temperature, dissolved oxygen, inorganic phosphate, nitrate, chlorophyll, and pH. Preliminary results indicate that oxygen depressions, although slight (80-90 percent saturation), occur at deeper levels due to the demand exerted by decaying algae and other organic matter which have settled through the water column. Periodic surveys of other intermediate reservoirs in the basin substantiate that conditions existing in Detroit Reservoir are typical of the larger, deeper reservoirs of the system.

SUMMARY

Although effects of impoundments on water quality are presently limited to taste and odor problems from algal activity in the relatively new reservoirs of the Willamette Basin, it is anticipated that degradation of water quality will occur in the future due to enrichment of reservoirs by nutrients. The degree of

degradation and time required for lake aging will depend on the efficiency of management and control of waste discharge practices.

Federal Installations

Significant waste loads emanate from Federal lands and facilities in the Willamette Basin. In addition to sanitary wastes from recreation facilities maintained on Federal lands, other sanitary and industrial wastes are contributed by military bases, office buildings, naval vessels, and other installations built and maintained by the Federal government. Treatment and disposal of these loads are as follows: 33 discharge to municipal sewer systems; 10 provide their own treatment; 60 dischargr to septic tanks and subterranean drainage facilities; and 156 are served by pit privies. Waste disposal practices at all these installations are in general considered to be satisfactory.

In addition, the Federal government has the responsibility of studying the problem of water pollution from vessels. Ocean-going vessels discharge untreated sanitary wastes from an estimated 525 Crewmen daily to the Portland harbor. Additional untreated sanitary wastes are discharged from valal vessels, tugboats, pleasure craft, and houseboats. Sanitary wastes may at times be equivalent to that of several thousand persons.

Storm Runoff

Stormwater runoff from urban areas causes pollution loads of minor significance in the Willamette Basin both directly and as the causative agent for bypassed sanitary sewage from the system or treatment facility in those communities served by combined sewer systems. There are some 80 sewage collection systems in the Willamette Basin, serving over one million people, or 85 percent of the population. The area served by collection systems is about 370 square miles, or 3.3 percent of the total basin area. Twenty-five percent of systems serving fifty percent of the people are wholly or partially of the combined type.

Most stormwater runoff occurs during the winter periods of heavy rainfall when streamflows are also high. During the critical summer period (July, August, and September), there is very little rainfall, and storm overflows are at a minimum.

While urban runoff is not a critical factor in determining water quality in the Willamette River Basin, the desirability of averting the overloading of waste treatment plants during heavy rainfall has been recognized. It is the firm policy of the OSSA to approve sewer systems only when they provide separate transmission of stormwater and of other sources of liquid wastes. The policy is reinforced by the requirement that separate storm and sanitary sewers be available as a condition for award of Federal construction grants.

WILLAMETTE BASIN WASTE DISPOSAL AT FEDERAL INSTALLATIONS

Number of Facilities	Name and Location	Average Flow gal/day
1	Metallurgy Research Center, Albany	150,500
1	V. A. Hospital, Portland	85,000
1	International Airport, Portland	450,000
1	Federal Interior Building, Portland	37,800
14	Post Offices	41,000
15	Office and Miscellaneous Buildings	56,200
33	SUBTOTAL TO CITY SEWERS	820,600
1	Timberline Lodge	60,000
1	Government Camp Recreation Area	63,000
1	SAGE Air Base, Corvallis	83,000
1	Indian School, Chemawa	80,000
1	Baker Bay Recreation Area, Dorena	8,000
1	Lookout Point Recreation Area, Lowell	6,500
4	Miscellaneous Dam Control Stations	1,000
10	SUBTOTAL TO SEPARATE TREATMENT & SURFACE DRAINAGE	301,500
17	Major Recreation Areas	58,800
4	Fish Hatcheries	5,600
18	Ranger Stations	31,200
6	Dam Control Stations	2,500
11	Power Substations	2,500
4	Minor Military Installations	1,500
60	SUBTOTAL TO SEPTIC TANKS & SUB-SURFACE DRAINAGE	102,100
19	Reservoir Recreation Areas	(4,670)*
133	Forest Recreation Areas	(7,945)*
4	Military Rifle Ranges	(735)*
156		
259	TOTALS	1,224,200

* *Estimated average population served.*

CHAPTER FIVE

EVALUATION OF SUBAREAS

Evaluation of subareas is presented herein in the form of a description of the role of water in principal Willamette River tributary basins and stream reaches. What it attempts to describe is the relation of uses and potential uses to water quality, and the development of an operating procedure for obtaining or sustaining the quality of water which is appropriate for the indicated uses.

To the extent possible, the analytical technique used to evaluate areas was mathematical, involving examination of data relationships with the assistance of a digital computer. Matters which did not fit into the dissolved oxygen schema, or those which were inappropriate due to the absence of data required for the mathematical procedures, were subjected to generalized technical examination.

In arriving at the set of evaluations presented in this report, only summer conditions were considered, because the most severe water quality problems of the Willamette River Basin are associated with the low flows and high temperatures characteristic of the summer situation of the system.

Intensity of study, and the depth in which situations are discussed, vary with the potential for pollution of individual tributaries and reaches. Concentration of waste discharges and the underlying physical conditions of the watershed combine to limit the areas which are, or are apt to be, subject to use-inhibiting pollution. The bulk of the attention given to pollution control measures in the Willamette Basin must be centered upon the South Santiam River, the Tualatin River, and the Portland harbor.

The computer program utilized to examine dissolved oxygen characteristics consists of a series of sequential

Willamette Basin major urban area

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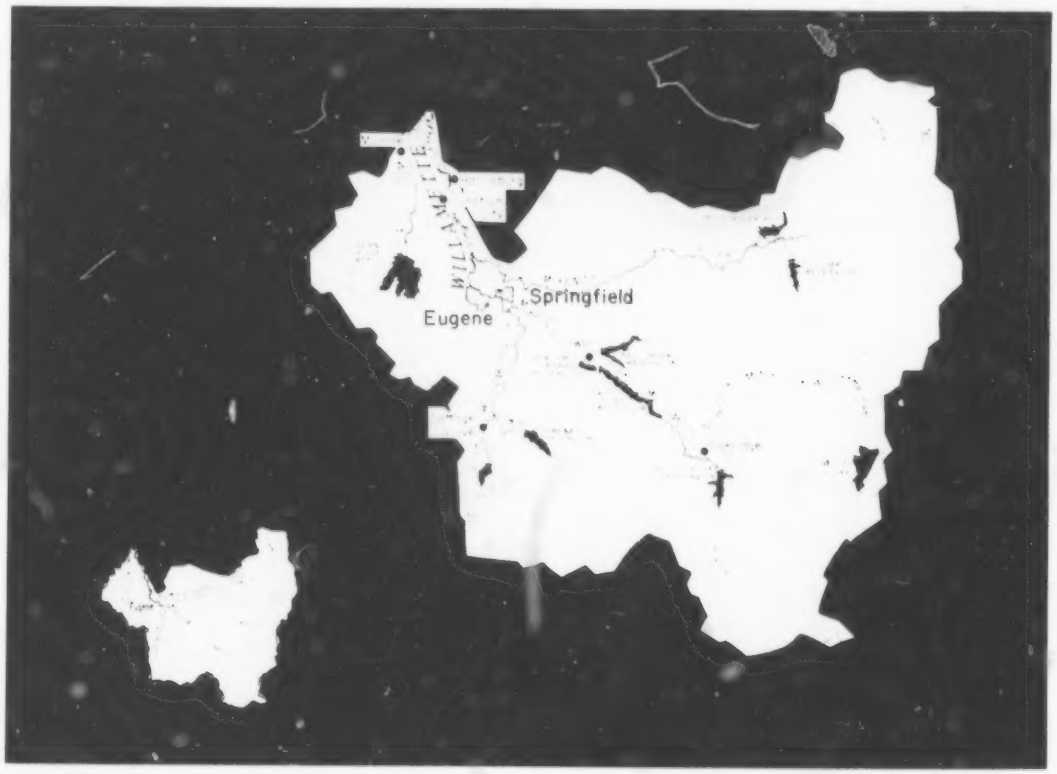
repetitions of the Streeter-Phelps equation, which relates the factors that define the dissolved oxygen resources of a water body. A mathematical expression of the governing set of physical conditions for the relevant stream reach--flow velocity, stream temperature, deoxygenation rate, reaeration rate--is programmed into the equation. Given a set of waste loads, the program then derives either flow needed to achieve a given level of dissolved oxygen, or the dissolved oxygen level that may be anticipated from a given flow.

Upper Willamette

SITUATION

The Upper Willamette Basin is that portion of the river system which extends from the headwaters to the mouth of the Long Tom River. It includes a portion of the drainage area of the main stem Willamette and all of that of the Middle Fork, Coast Fork, McKenzie, and Long Tom Rivers. Drainage area is about 3,900 square miles, or 32 percent of the total of the Willamette Basin.

Most of the land mass is mountainous and thickly forested, with Douglas fir predominant. The valley floor begins to widen near Eugene, where the Willamette receives the McKenzie, its largest tributary. But only a narrow strip of cultivated valley, extending along the main stem of the Willamette and along the Long Tom River below Fern Ridge Dam, breaks the prevailing upper basin pattern of mountain and forest.



Forest products provide the foundation of the area's economy, accounting for about 85 percent of total manufacturing employment. Location of the University of Oregon at Eugene, however, has given the area an unusual bias in the direction of service industries. Eugene serves as the center for services of much of southwestern Oregon; and the recreational opportunities that arise in the upper basin's large tracts of forests and clear, clean rivers have extended the emphasis on services beyond the population and industrial focus formed by Eugene. Agriculture and food processing constitute a third source of income for the region, providing it with a sound, diversified economy.

Though it contains roughly a third of the Willamette Basin's land area, the upper basin holds only about 13 percent of the total basin population. Of its population of about 160,000, more than 105,000 persons are concentrated within a fifteen mile radius of the center of the city of Eugene. Eugene--Oregon's second largest city in terms of population--and Springfield--Oregon's sixth--face one another across the Willamette River and have a combined population of roughly 93,000. Since World War II, the two towns have consistently led all other Oregon communities in rate of population growth. Cottage Grove on the Coast Fork of the Willamette and Oakridge on the

Middle fork contain the only significant population clusters outside of the immediate influence of Eugene, with 5,000 persons living in the area of Cottage Grove, and 3,000 at Oakridge.

Economic growth of the area has been based on the southward movement of Oregon's lumber industry and the expansion of the University of Oregon. The sawmills and plywood mills which exist throughout the upper basin tend to be large, efficient installations whose waste wood provides the raw material for Oregon's largest pulp and paper plant, the 1,150 ton per day Weyerhaeuser mill at Springfield, and for several particle board plants which have been built since 1960.

Water resources of the area are rich, including the main forks of the Willamette, the McKenzie system, and the Long Tom River drainage. With the exception of the Long Tom, these are swift-flowing streams, with steep slopes and rocky beds, passing through mountainous terrain in most of their drainage areas. Because of its physical conformation, the upper basin provides a number of excellent reservoir sites, and these have been utilized to a high degree. Total reservoir storage capacity in the upper basin amounts to about 1.25 million acre-feet, about 55 percent of the Willamette River system total with proposed development.

The quality of the waters of the upper basin is for the most part excellent, little degraded from its natural state, except, perhaps, in impoundments. Exceptions include high bacterial counts in the Willamette River below Eugene, seasonal turbidity during winter floods, high summer temperatures and rather constant turbidity on the Long Tom, and intermittent slime growths below the south of the McKenzie.

Weyerhaeuser Company's pulp and paper plant at Springfield provides a high degree of waste reduction. Uncontrolled pulping liquors are condensed and burned for recovery of cooking chemicals (smokestacks at right). Fibers and other solids are settled out in the two small ponds near the center of the picture. Residual wastes are held up to five days in the large lagoon. Here aerators float, added oxygen runs the waters to facilitate waste decomposition. (Weyerhaeuser photo)

JULY 1965

INVENTORY OF MAJOR WASTE SOURCES

UPPER WILLAMETTE RIVER BASIN

* Reference Community or Industry	River Mile	Pop. Served	Untreated * Waste PE	Treatment	Capacity, Design PE	Const. Date	Discharged * Waste PE	Needs	Status of Improvement
[illegible]									
[illegible]									
[illegible]									
[illegible]									
[illegible]									
[illegible]									
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The relative absence of water quality problems may be attributed in part to the physical characteristics of the rivers of the upper basin--cool, shallow, swift-flowing streams with high reaeration rates and high rates of waste transmission--in part to relatively low waste loads. The total organic waste production of the area amounts to only some 360 thousand population equivalents; and efficient waste treatment lowers this number to about 120 thousand population equivalents of discharged wastes.

The principal waste source of the area is the Weyerhaeuser Company pulp and paper mill at Springfield. The mill, whose waste removal practices are exemplary, employs the sulfate pulping process, recycling of process waters, primary and secondary waste treatment, and summer spray irrigation with waste waters to minimize effects on the quality of the river. Following the plant's expansion from production capacity of 450 tons per day to 1,150 tons per day during 1965, problems of slimes, odors, and discoloration were noted in the lower McKenzie. The plant began the installation of additional treatment facilities--including an aerated lagoon providing secondary waste treatment--in order to overcome these problems of expansion.

The city of Eugene--whose wastes are seasonally increased by about 150,000 population equivalents by industrial discharges to the municipal treatment plant--has consistently expanded its waste treatment capacity at a rate commensurate with its increased waste production. Secondary waste treatment plants are operated at Lowell and Springfield, planned or under construction at Cottage Grove, Oakridge, Junction City, and Harrisburg.

The one exception to the general willingness of upper basin municipalities and industries to provide waste treatment is the community of Monroe. This tiny hamlet--population 350, assessed valuation $300,000--has for twenty years evaded its responsibilities and the instructions of the OSSA by continuing to discharge untreated wastes into the Long Tom River. The significance of these discharges, however, must be considered largely symbolic, since water quality remains high. The average dissolved oxygen concentration near the mouth of the Long Tom River--that is, below the waste discharges of Monroe--has averaged fractionally more than 8 mg/l, ranging from 90 percent to 115 percent of saturation. The lowest recorded dissolved oxygen determination--taken in the drought summer of 1965 when dissolved oxygen in the Portland harbor was less than 2 mg/l--was 5.7 mg/l. Counts of coliform bacteria have ranged from 22 to 24,000 MPN, with the median being about 2,000 MPN, or less than five percent of that of the receiving Willamette at their confluence.

The rapid growth of population and industrial output that has marked the upper basin over the last two decades is expected to persist well into the future, with a corresponding expansion of waste loads occurring. Most of this growth is expected to continue to occur in the Eugene-Springfield area, and to rest on expansion in other fields to a greater extent than on pulp and paper--though output of pulp and paper is expected to grow in a very vigorous fashion. It is anticipated that 1985 waste production will be about two and a half times that of 1960, which means that the area will have to achieve about 90 percent waste reduction in order to maintain discharges at the level presently achieved by a 65 percent over-all reduction. Even higher levels of waste treatment must be accomplished in later years.

WATER USES AND QUALITY OBJECTIVES

Municipal and industrial water supplies, production of salmonid fish, and recreation are the principal quality-demanding uses of upper basin waters. Irrigation and stock watering, uses of

UPPER BASIN, ESTIMATED AND PROJECTED WASTES
(1,000's PE)

LOCATION	ESTIMATED WASTES 1964		PROJECTED WASTES	
	Total	Discharged	1985	2010
Eugene-Springfield	362.8	111.8	953.7	1528.3
Cottage Grove	6.0	3.7	12.4	24.2
Other Coast Fork	2.3	0.5	3.8	7.2
Oakridge	4.6	2.1	9.6	18.8
Other Middle Fork	0.7	0.1	2.5	6.2
McKenzie	0.7	0.5	3.7	6.2
Long Tom	0.4	0.4	2.5	6.2
Total	377.5	119.1	988.2	1597.1

The Long Tom River, with its lesser natural quality, does not present the same level of opportunity for recreation, fishery use, and water supply that the other major upper basin tributaries provide. Natural turbidity, untreated waste discharges of Monroe, extremely high summer temperatures in the lower river, and noticeable algal blooms all lessen the attractiveness of the river for many purposes. On the other hand, rainbow trout are found in the upper reaches of the stream; and Fern Ridge Reservoir, which supports over 300,000 visitor days of use per year, experiences the highest density of swimmers and boaters per surface acre of any water body in the State of Oregon. The reservoir, a few miles from Eugene, has been a major recreational point for many years; and the suburban population of Eugene, spreading westward, may be expected to exert a steadily greater demand on the recreational and aesthetic resources of Fern Ridge Reservoir and the Long Tom River. The Long Tom is also more heavily used for irrigation than the other tributaries of the Willamette in the upper basin.

Uses of the main stem of the Willamette River include salmon passage, a minor amount of salmon spawning, fish habitat, game fishing, and bankside recreation. Swimming and other types of water-contact recreation are limited by the excessive bacterial concentrations that occur in the river below Eugene. Propinquity to a large urban population and the existence of bankside recreation areas result in frequent summer use by swimmers, even though the river is posted against swimming at most of the often-used access points. As in the case of the Long Tom, considerable use of the river is made for irrigation and stock-watering in the agricultural lowlands below Eugene.

Because of the nature of uses, the primary water quality objectives are those relating to dissolved oxygen, temperature, and bacteria. Maintenance of a dissolved oxygen level of no less than 7 mg/l throughout the waters of the upper basin is necessary in view of the large part the area plays in maintaining salmon runs. In spawning areas, influences that result in a deviation from oxygen saturation should be stringently eliminated. Except in the Long Tom, where natural conditions are not suitable in the lower river, summer water temperatures that do not exceed 70 degrees may be considered a desirable fishery objective. The warm-water game fish which are proper to the lower Long Tom do not impose a temperature requirement. Bacterial concentrations below 1,000 MPN should obtain wherever possible. In reservoir situations, which are marked by extensive summer water-contact recreation, the bacterial objective is critical, and lowering the bacterial density characteristic of the main stem Willamette in the vicinity of Eugene would be particularly useful in providing ready access to water-contact recreation for the large population of the Eugene-Springfield area.

QUALITY MANAGEMENT PROGRAM

Maintenance of the quality of water necessary to serve uses which occur in the upper Willamette Basin appears to be largely a matter of providing adequate waste treatment. The high natural quality of the waters of the upper basin and the high degree of assimilative capacity provided by rapid, shallow flows largely obviate the need for flow regulation or sophisticated management techniques.

In the interest of good practice, and in order to reduce residual wastes being borne downstream, the OSSA's policy of requiring secondary waste treatment by all communities should be continued, and extended to such significant sources of industrial wastes as may develop at a later date. Eugene's practice of combining municipal and industrial waste treatment would appear to represent an optimal approach to the problem of providing treatment for expanding industrial wastes, and should be considered as a model by other communities which are planning for future industrial growth.

The immediate waste treatment needs of the area are clearly defined; and, with the exception of the community of Monroe, residents of the area are working to meet them. These needs include completion of secondary treatment plants at Cottage Grove, Oakridge, Junction City, and Harrisburg, enlargement of Eugene's secondary treatment capabilities, and installation of primary and secondary treatment at Monroe. The Weyerhaeuser Company's waste disposal program seems entirely adequate to meet the needs posed by expansion, as do the waste treatment capabilities of Creswell, Springfield, and Lowell.

Waste treatment practices of sawmills and plywood mills should receive considerably more attention than in the past. In the operation of such industrial plants, every effort should be made to lessen the amounts of solids that reach watercourses. In particular, plants which utilize hydraulic barkers should provide primary treatment for the wastes of barking. The level of biochemical oxygen demand occurring as a result of barking--about 2.5 pounds per cord--is of little significance or potential signifi-

cance to the water quality of the upper Willamette; but the suspended solids which occur from barking--up to 25 pounds per cord--can be a potential source of aesthetic damages, and of materials which serve as a base for attachment of *Sphaerotilus*.

While it does not appear that waste loads sufficient to require flow regulation will exist in the upper basin within the next two decades, it is probable that flow regulation required in downstream areas will be accomplished in part with storage in upper basin reservoirs. Should this prove to be true, flows provided for quality regulation might best be released from reservoirs other than Fern Ridge, whose high summer temperature makes it's waters of less utility for quality control needs than that of upstream reservoirs on the Middle Fork Willamette and the McKenzie.

Practices to control wastes hold a large measure of opportunity to maintain the high quality of the waters of the upper basin, passing it to downstream areas in which pollution occurs and which benefit far more than the upper basin from any increment in the quality of incoming waters. Such practices include application of soil conservation measures in agriculture and logging, and the separation of animal herds from the banks of streams. In the Eugene-Springfield area, great attention should be devoted to effectiveness of waste disinfection, since the bacterial concentrations that occur below Eugene present the principal water quality problem of the upper basin. Related to both soil conservation and disinfection is urban land drainage, which may be presumed to add to both bacterial concentrations and turbidity. While the present requirement of the OSSA for separation of storm water and sanitary sewers should ultimately alleviate pressure of urban drainage problems, acceleration of the program through planned installation of separate storm water sewers--particularly at Springfield--would probably confer many benefits on the water quality of the of the main stem Willamette.

A significant measure which should be instituted--not for its effects on water quality of the upper basin, but for the sake of the quality of the entire Willamette River system--is promotion of industrial development on the main stem Willamette in the upper basin, in preference to downstream areas. By utilizing the great assimilative capacity of the upper river in such fashion, it is possible to maintain the use-serving quality of the Willamette River while postponing costs of additional flow regulation and the ultimate need for advanced waste treatment procedures.

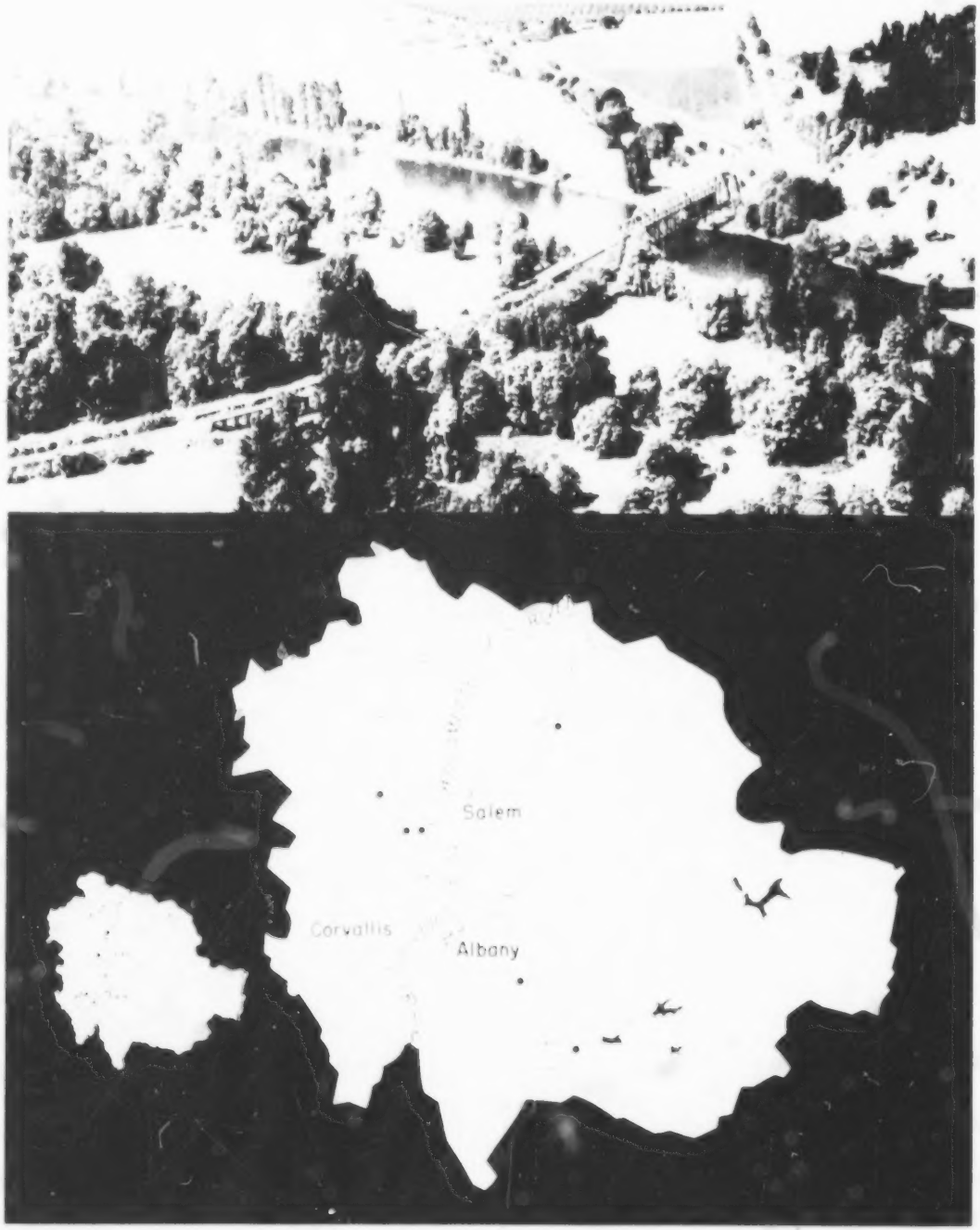
Because of the generally high quality of the waters of the upper basin, it does not seem necessary to install an extensive water quality monitoring program for the area. The OSSA's program of summer monitoring of the main stem and tributaries, combined with additional sampling when special situations indicate a need, seems entirely adequate to provide a consistent picture of the water quality of the sub-region and its relation to quality modifications that may occur downstream. Properly to complement the in-stream water quality sampling program, a system of consistent, periodic reporting of waste discharges to the OSSA should be instituted, including details of volume of discharges and quality of the effluents. Reporting should be supplemented by periodic in-plant sampling of major waste sources by the OSSA. Reportees should include the cities of Eugene and Springfield, the Weyerhaeuser Company's forest products plant at Springfield, and such other industrial plants and municipalities as the OSSA considers appropriate.

Middle Willamette

SITUATION

The middle Willamette Basin is considered to be that portion of the Willamette drainage area which extends from the mouth of the Long Tom River to the mouth of the Tualatin River. It includes the watersheds of the Calapooia River, the Santiam River system, and the Molalla-Pudding River systems, which originate in the Cascade Range and enter the Willamette from the east, and the Coast Range-fed Marys River, Luckiamute River, Rickreall Creek, and Yamhill River. The drainage area of the middle basin includes more than 5,400 square miles, or about 45 percent of the total for the Willamette River system.

The valley floor is wider in this portion of the basin than in headwaters area, and rolling foothills of the Cascade and Coast Ranges extend the land area suitable for agricultural use into a broad belt of cutover land extending to the east and west, and particularly up the valleys of tributaries.



Economically the area is oriented to agriculture which occupies almost ten percent of its labor force. The large and varied agricultural production is largely processed within the subarea and supplemented by shipments from other Puerto Northwest regions. The output of canned foods from Salem, the largest city of the middle Willamette, has for some years exceeded that of any other United States community, and lesser food processing concentrations are found in Stayton, Woodburn, Corvallis, and other places. Western Oregon's characteristic dependence on forest products manifests itself in the middle basin, though to a lesser extent than in coastal and southern areas of the region. Logging has been conducted at or above the sustained yield level for many years, with the consequence that expansion of forest products output has come entirely from superior utilization procedures, notably the use of sawmill and plywood mill residues in production of particle board and pulp and paper. Pulp and paper plants are found at Lebanon on the South Santiam River and at Albany, Salem, and Newberg on the Willamette River. Presence of the U. S. Bureau of Mines laboratory at Albany has fostered the development of a significant metals industry in that place, with two firms engaging in the fusion reduction and extensive fabrication of titanium and exotic metals. Services are concentrated in Salem, Oregon's capital, and Corvallis, the site of Oregon State University. The presence of Oregon College of Education at Monmouth provides a somewhat unusual service flavor to that basically agricultural and rural community.

Population of the area is less than 320,000 persons, about a quarter of the total Willamette Basin population. To a

large extent these people live in a number of small communities and in the countryside. Population concentration manifests itself at Salem with its more than 50,000 residents, Albany, about 13,000, and Corvallis, about 22,000, which together account for a little more than a quarter of the subarea's residents.

Growth of the area has been gradual and regular. Its socio-economic patterns have been fixed for decades and are marked by an orientation to rural values and steady economy that is quite distinct from the attitudes toward regional economic growth that prevail in the upper and lower subbasins of the Willamette.

Water resources are limited, when contrasted to those of the upper basin. The lesser elevations of the mountain sources of tributaries and the greater width of valley floor results in smaller, slower flowing streams than those which feed the Willamette in the upper basin. The Santiam system, with its average August flow of about 850 cfs, is the only middle basin tributary which provides a substantial flow throughout the year. There are few reservoir sites; and water resource projects provide less than 345,000 acre-feet of storage in the area at this time; almost all of it--340,000 acre-feet--is in Detroit Reservoir on the North Santiam River. Another 510,000 acre-feet of storage is authorized and under construction on the Santiam system, which, with 90,000 acre-feet of proposed storage on the Calapooia and 50,000 acre-feet of storage on the Yamhill, largely exhausts the likely storage sites in the region.

Quality of the waters of the middle basin varies with place and time. With the exception of turbidity, which occurs during the winter period of high runoff, and bacterial concentrations, which tend to be high through the year, loss of quality is associated with low summer flows. The quality of the waters of the Willamette is excellent as it enters the middle basin, considerably lessened as it leaves. Dissolved oxygen concentrations range very closely about the saturation level from the mouth of the Long Tom River to Newberg, but decrease during summer to about 5 mg/l in the stretch of river between Newberg and Willamette Falls. Summer temperature increases slightly between the head of the subarea and Willamette Falls, rising from an average 68 degrees (F) to 71 degrees. Bacterial concentrations throughout the middle basin passage of the Willamette River are above the recommended recreation objective of 1,000 MPN; however, in recent years, concentrations have been dropping--presumably as a result of more effective disinfection of municipal wastes--and approach the recreation standard in several reaches of the river. The appearance of the Willamette is damaged as it passes through the 120 miles of the subarea. Silt, fiber, and solids become increasingly apparent; and *Sphaerotilus* begins to appear in the stretch of river below Newberg, clinging to banks and attaching to floating objects.

A major cause of the decline in water quality that occurs below Newberg is the change in hydraulic characteristics of the Willamette at that point. From its headwaters to the mouth of the Yamhill River, the Willamette is shallow and swift-flowing. The river travels about a mile to a mile-and-a-half per hour from the mouth of the Long Tom River to Newberg during the summer, achieving a high degree of turbulence and atmospheric contact and moving dissolved organic materials at a rapid rate. Near Newberg and the mouth of the Yamhill River, however, the Willamette enters a deep--about 20 feet--pool in which a much lesser surface area-to-volume relationship and a much slower rate of passage (about 0.3 miles per hour) inhibit atmospheric contact and reaeration as well as the rate of materials transmission. The effect is a distinct rise in the rate at which oxygen utilization occurs relative to distance in company with a drop in the rate of reaeration. The slower rate of passage also increases exposure to solar radiation, causing a rise in temperature.

Among the tributaries, the Marys River, the Luckiamute River, Rickreall Creek, and the Calapooia River are much alike in quality. Dissolved oxygen concentrations are generally near saturation--presumably due to absence of organic wastes--though the levels sometimes drop as a result of flow depletion. Irrigation demands on these modest streams may cause them to run dry or to be limited to small pools during protracted dry periods. Summer temperatures customarily exceed 70 degrees; bacterial concentrations are characteristically well above 1,000 MPN; and excessive turbidity is very common in these small, sluggish watercourses.

Quality in the Yamhill River and in the Molalla-Pudding River system is much alike. In each case, the upper reaches of the streams are clear, free-flowing water bodies of moderate temperature, high dissolved oxygen content, and low bacterial concentrations. In each case, the major communities based upon the river (McMinnville, Sheridan, and Carlton in the case of the Yamhill; Woodburn, Silverton, and Molalla in the case of the Molalla-Pudding) are situated well above the mouth of the stream. Yet, in each case the lower reaches of the stream are subject to summer degradation in water quality. This manifests itself in an extreme level of turbidity, water temper-

discharged to the Willamette River watershed. The principal sources are manufacture of pulp and paper and the processing of foodstuff. The total estimated organic waste load produced in the middle basin amounts to about 3.1 million PE, which is reduced to about 1.9 million PE by waste treatment. During the critical summer months, holdover storage is brought into use; in consequence, waste discharges to watercourses during the period of low flows amount to about 800,000 PE of oxygen-demanding materials.

The greater part of this waste material is produced beside, and discharged into, the Willamette River. Almost 2.4 million PE of wastes are produced along the Willamette, most of it in the Salem, Albany-Corvallis and Newberg service areas. Average discharges of treated wastes by Willamette River sources amount to about 1.8 million PE. Of the remaining wastes of the subarea the most significant amount occurs along the South Santiam River an amount that exceeds half a million PE. Waste treatment reduces this to a discharge of just over 60,000 PE.

The major waste sources are the four pulp and paper mills. Three of these--at Lebanon on the South Santiam, and at Salem and Newberg on the Willamette--are sulfite process pulp mills, with a very high waste-to-product ratio. The Albany mill of Western Kraft is a sulfate process mill distinguished by the lower waste-to-product ratio that is obtained in sulfate pulping in which digester wastes are condensed and burned in order to recover cooking chemicals in gaseous form. As a group, these four mills account for 70 percent of the total organic waste production of the subarea and for over 90 percent of the average waste discharge.

When the mills are evaluated as a group, their waste treatment practices must be considered to be extremely unsatisfactory. The Albany sulfate process plant achieves significant reductions in waste strength--in addition to the major reduction that occurs through materials recovery--by recycling condensates and by providing primary settling. The Lebanon plant of Crown Zellerbach Corporation condenses the major portion of its pulping liquors, some of which is dried and sold to several markets that exist for the by-product, some of which is burned in a manner analogous to that employed for chemical recovery in sulfate mills. In distinction, the Newberg and Salem plants provide no waste treatment, restricting their waste reduction practices to storage in holding ponds during low flow periods, with discharge made during higher flows.

Recognizing that the situation is incompatible with desired water quality goals, the OSSA has instructed all of the mills in the Willamette River Basin to install primary treatment facilities by the summer of 1968. The Authority has also provided to the mills a schedule of allowable low flow waste discharges that is predicated on the existing flow regulation schedule of the Willamette Basin. The schedule establishes the permissible upper limit of discharges for: Western Kraft, about 30,000 PE; Boise Cascade at at Salem, about 60,000 PE; Publishers Paper at Newberg, about 90,000 PE; Crown Zellerbach at Lebanon, about 30,000 PE. While waste reductions of this magnitude can be attained through treatment, it is the present policy of the OSSA to accept storage of wastes during low flows as a substitute for treatment beyond the primary level.

Two of the four pulp and paper plants are very unfortunately located. Because of the low and intermittent summer flows of the South Santiam, the wastes of the Lebanon mill have created a perennial pollution problem. The Newberg mill is situated at the head of the Newberg pool, where the assimilative capacity of the Willamette River is sharply reduced by ponding. Thus, the impact of the oxygen demand of the waste discharge of this mill is much more powerfully reflected than it would be if it occurred at an upstream point; and the sharp reduction of the quality of the lower Willamette river begins at Newberg. In 1965 a major expansion of the facility was initiated. Fully realizing that Newberg probably represents the most undesirable point on the Willamette River for expansion of waste loads, the OSSA instructed that primary treatment and a very significant expansion of wastes storage capacity--to 120 million gallons--be provided. It also indicated to the operators of the mill that future installation of pulp liquor recovery facilities might well be required of them.

Experience with storage of pulp mill wastes has indicated that it is an inappropriate method to be relied upon for a long-term solution to the problem of waste reduction. In theory, it provides for a fuller utilization of the assimilative capacity of the stream by gearing waste discharges to flows, which is un-

WASTE REDUCTION
MIDDLE BASIN PULP AND PAPER MILLS

	Total	Reduction By Treatment	Reduction By Storage
Crown Zellerbach	525.0	468.6	-
Western Kraft	114.0	50.8	-
Boise Cascade	826.0	-	796.0
Publishers Paper	774.0	-	301.0

INVENTORY OF MAJOR WASTE SOURCES – MIDDLE WILLAMETTE RIVER BASIN

JULY 1965

Watercourse Community or Industry	River Mile	Pop. Served	Untreated Waste PE	Treatment	Capacity Design PE	Const. Date	Discharged Waste PE	Project Needs	July 1965 Status of Improvement
Marys River	132								
Philomath	10	1,300	1,300	Secondary	1,800	1952	200	None	--
Corvallis	131	22,000	120,000	Primary	28,000	1954	84,000	Secondary	Under construction
Evans Products		--	9,000	None	--	--	9,000	New plant	None
Bowers Slough	123								
Adair Air Force Base	4	700	700	Secondary	750	1959	100	None	--
Calapooia River	120								
Brownsville	33	600	600	Lagoon	1,000	1964	120	None	--
Albany	119	14,000	80,000	Primary & addtl. biological trtmt.	32,000	1954	48,000	Secondary	Preliminary plan
Western Kraft		--	114,000	In-plant cont. primary	--	-- 1965	63,200	Secondary	In-plant improvements
Santiam River	109								
South Santiam River	12								
Sweet Home	32	3,500	3,600	Secondary	3,500	1948	720	Enlarge	Final plan
Lebanon	17	6,400	7,500	Secondary	10,000	1958	2,400	None	--
U. S. Plywood		--	7,000	Lagoon	--	--	2,400	None	--
Crown Zellerbach	15	--	525,000	Recovery	--	--	56,400	Primary Secondary	Preliminary primary plan
North Santiam River	12								
Stayton	28	2,000	2,000	Secondary	3,500	1964	400	None	--
Stayton Canning Co.		--	70,000	Land	--	--	0	None	--
Paris Woolen Mills		--	4,800	Land	--	--	0	None	--
Jefferson Woolen Mills	9	--	4,200	Lagoon	--	--	840	None	--
Independence	96	4,500	4,800	Primary	6,000	1951	3,500	Secondary	Final plan
Ash Creek	95								
Monmouth	1	2,000	2,000	Lagoon	8,000	1963	400	None	--
Rickreall Creek	88								
Dallas	12	5,400	8,400	Secondary	8,000	1952	1,260	Enlarge	Preliminary plan
Salem	80	60,000	390,000	Secondary	455,000	1964	58,500	None	--
Boise Cascade Corp.		--	826,000	Holding pond	--	--	30,000	Recovery Primary Secondary	Preliminary primary plan
Lake Labish Ditch	78								
Chemawa Indian Agency	6	900	900	Lagoon	1,500	1965	60	None	--
Alderman Farms #1	67	--	7,500	Land	--	--	0	None	--
Yamhill River	55								
South Yamhill River	11								
Sheridan	37	1,700	1,700	Secondary	2,500	1962	560	None	--
McMinnville	5	8,000	12,900	Secondary	8,000	1964	2,580	Enlarge	No plan
North Yamhill River	11								
Yamhill Labor Camp	5	1,000	1,000	Secondary	1,300	1941	120	Replace	Under construction
Carlton	5	1,000	1,000	Secondary	1,500	1955	200	None	--
Lafayette	8	500	500	Lagoon	675	1964	100	None	--
Alderman Farms #2	5	--	6,000	Lagoon	--	--	0	None	--
Newberg	50	4,200	6,000	Secondary	8,000	1963	900	None	--
Publishers Paper Co.		--	774,000	Holding pond	--	--	373,000	Recovery Primary Secondary	Preliminary primary plan
Corral Creek	40								
Dammasch Hospital	1	1,000	1,000	Secondary	2,500	1963	150	None	--
Molalla River	36								
Pudding River	1								
Silver Creek	49								
Silverton	3	3,600	20,000	Secondary	28,000	1963	3,000	None	--
Mt. Angel	34	1,200	6,200	Secondary	5,000	1955	930	Enlarge	No plans
Bear Creek									
Molalla	10	1,400	1,400	Secondary	3,000	1955	210	None	--
Mill Creek	7								
Woodburn	9	4,000	5,400	Secondary	9,560	1964	810	None	--
General Foods		--	42,000	Land	--	--	0	None	--
Canby	34	2,000	2,400	Secondary	2,000	1963	360	None	--

questionably a desirable practice. Problems occur, however, during protracted dry periods, which result in complete filling of waste holding ponds and subsequent overflow--or the necessity for plant shutdowns. Loss of holding capacity as a result of accident can result in devastating slug loads of concentrated wastes. The fibers and nutrients that make up a good portion of the volume of the wastes stimulate growths of *Sphaerotilus* and algae when they are released during high flows, since releases must of necessity be concomitant with the regular discharge of mill wastes. (Installation of primary treatment, with removal of suspended fibrous materials, may, however, alleviate a good portion of undesirable effects of this sort.)

As opposed to the pulp and paper industry, the food processing industry of the middle Willamette has done an excellent job of reducing its wastes. Large plants at Stayton, on the North Santiam River, and at Woodburn, on a tributary of the Pudding, practice land disposal of their wastes, virtually eliminating them from watercourses. At Corvallis, Albany, Salem, McMinnville, and Mt. Angel, food processing wastes are treated in the municipal waste treatment plants. The recently completed Salem waste treatment plant is an outstanding example of municipal and industrial cooperation in the interest of pollution abatement. The plant is designed to handle a population equivalent of oxygen-demanding wastes that is almost eight times the population of the community. Very effective treatment results from the mixture of the higher temperatures and sugar content of the wastes of food processing with the domestic wastes. The variety of products that is processed in the Willamette Basin makes it possible to utilize a good portion of the capacity of the

Four Willamette Basin pulp mills store their wastes in holding ponds--like this one at West Linn--during the summer. Untreated wastes are discharged when streamflow rises.

Salem sewage treatment plant

MIDDLE BASIN, ESTIMATED AND PROJECTED WASTES
(1000's PE)

LOCATION	ESTIMATED WASTES 1964		PROJECTED WASTES	
			1985	2010
	Total	Discharged		
Albany-Corva'lis	873.5	206.9	1211.6	1579.8
Salem	1231.8	886.6	2522.7	7842.6
Newberg	780.0	774.7	1666.8	2798.5
Other Main Stem	15.6	1.0	45.5	91.6
Calapooia	1.3	0.3	6.1	10.3
Santiam River[1/]	83.2	1.9	164.9	315.1
McMinnville Area	12.9	2.6	22.8	36.8
Other Yamhill River	11.7	0.3	22.9	43.2
Woodburn Area	47.4	0.8	97.7	190.5
Silverton Area	20.0	2.9	44.1	83.2
Other Pudding River	7.3	1.4	17.5	31.0
Molalla River	3.6	0.5	22.1	41.8
Total	3088.3	1879.9	5844.7	13,298.1

1/ Plus 539,500 PE of total wastes and 61,200 PE of discharged wastes was tabulated under the Albany-Corvallis service area.

plant throughout the year, without encountering the long slack periods that occur where food processing is seasonal. Deficiencies in treatment of food processing wastes at Corvallis, Albany, McMinnville, and Mt. Angel are largely the result of expansion. For the most part, otherwise adequate facilities are required to handle a volume of wastes that is beyond their capacity. At Corvallis, only primary treatment is provided, but a secondary waste treatment plant is being constructed. Since the Corvallis wastes represent the largest block of municipal and food processing wastes not presently receiving secondary treatment, completion of the facility will represent a large increase in overall basin efficiency.

Municipalities of the middle basin have executed their waste treatment responsibilities in an exemplary fashion. With three exceptions--Corvallis, Albany, and Independence--every community provides secondary treatment of its wastes, including wastes of food processing in several instances. Corvallis is constructing a secondary plant; and Albany has a partial secondary treatment plant, operating a trickling filter but lacking a secondary clarifier. Four towns--Sweet Home, McMinnville, Dallas, and Mt. Angel--have exceeded the capacity of secondary treatment plants that were built in the decade after World War II. Of these, Dallas, Independence, and Sweet Home are planning the necessary expansion.

Wastes produced in the middle Willamette are expected to continue to increase at a moderate rate, with total waste production in 1985 forecast to be about 90 percent greater than in 1965. The rate of increase could be slowed substantially by a change in the situation of the area's sulfite pulp and paper mills, which are quite old. The vastly lower waste loadings that result from production of the sulfate process, or other processes employing a soluble base, would permit a considerable increase in wastes produced by other sources without the imposition of an increase in the total waste production of the area.

While substantial growth of the waste production of Salem and Newberg is anticipated in the future, the pattern of dispersion that marks the area is projected to continue, with several smaller communities experiencing an expansion of waste production at a rate at least as great as that of Salem. This may in some cases require stringent treatment measures to prevent pollution of tributaries. For the complete subarea, a reduction of waste strength of 67 percent will be necessary to maintain waste discharges at the stage presently attained with a 40 percent degree of removal. In point of fact, however, an even higher level of waste reduction must be achieved if pollution conditions are to be avoided. With present levels of waste treatment, the South Santiam becomes polluted each summer; and in the Newberg pool the conditions that result in the pollution of Portland harbor are initiated.

WATER USES AND QUALITY OBJECTIVES

As in other portions of the Willamette River Basin, the principal quality-demanding uses of water in the middle basin are production of salmonid fish, municipal and industrial water supply, and recreation. Considerable irrigation demand for surface waters also exists in this portion of the watershed; and navigation--principally log rafting--is practiced in the Willamette River below Corvallis.

Uses which can be served by the smaller tributaries--Marys River, the Luckiamute,

Rickreall Creek--are sharply limited by low summer flows and high temperatures. Rainbow and cutthroat trout and a limited number of coho salmon utilize the streams, though summer conditions which limit them to headwaters t strict supportable populations. Recreational use is generally constrained by low flows and turbidity, although some portions of Marys River do receive substantial recreational use. Rock Creek, a tributary of Marys River, provides the Corvallis water supply except during the summer period, when the city uses water taken from the Willamette. Rickreall Creek serves as a water supply to the town of Dallas; and the Luckiamute system provides a water supply for Monmouth. Irrigation is an important function of each of these systems; and stock watering occurs naturally along their banks.

The South Santiam and the Calapooia both provide upstream spawning areas for anadromous salmonids, as well as serving as a habitat for resident trout. In each case, however, low summer water quality in the lower reaches constitutes a severe constraint upon supportable populations. In the case of the Calapooia, temperature in the lower reaches is the main limiting factor. With the South Santiam, the limiting effects of an unsuitable temperature are reinforced by a severe oxygen deficiency. Neither stream offers a very broad recreational appeal, though limitation of the floating materials, slimes, and sludges which characterize the South Santiam would do much to expand opportunities for bankside recreation. The Calapooia is the source of the water supplies of the towns of Brownsville and Lyons. The South Santiam receives extremely heavy drafts for municipal supply purposes, serving Albany, Lebanon, and Sweet Home. There is limited irrigation and stock watering use made of the South Santiam; but these functions are important uses of the Calapooia.

The North Santiam, whose quality and appearance materially exceed that of the other streams of the middle basin, is also more intensely utilized for quality-demanding water uses. As a recreational resource, in particular, the North Santiam is very intensely utilized--partially as a result of lack of suitable alternative sites for water-based recreation. The focus of this recreational intensity is Detroit Reservoir, whose annual use by boaters, swimmers, fishermen, and others is fast approaching a half million visitor days. The North Santiam is a prime habitat for resident and migrant salmonid fish, ranking below only the Clackamas and McKenzie Rivers among the waters of the Willamette in its production of trout and salmon. Its utility in this regard has been recognized by anglers, who make up a good portion of the total number of recreationists who utilize the North Santiam, as well as by the Oregon State Game Commission, which operates an aggressive fish stocking program within the watershed. The North Santiam also provides the water supply for the Salem area, as well as for Stayton, Gates, and Mill City.

The Molalla-Pudding system is a habitat for the full range of salmonid fish species found in the Willamette Basin. The Pudding offers only trout and coho salmon; and the Molalla includes chinook salmon and steelhead. Recreational use of the rivers is moderate, due to the modest population of their watersheds. The total, however, is being increasingly supplemented by residents of the Portland area. Some moderate irrigation and stock-watering demands are also levied on both the Molalla and the Pudding.

The Yamhill River supports both resident and anadromous salmonids in its upper reaches, but high summer water temperatures in the lower stretch of the river make much of it unsuitable for higher types of game fish through a good portion of the year. There are several public parks and boat launching facilities along the lower Yamhill; but use of these facilities for water-contact sports is not practical because of high prevailing bacterial concentrations. Turbidity, floating materials, and algae all serve to make the lower portion of the watercourse unappealing for recreation, in any event. Irrigation and stock-watering are significant uses of the river.

The middle reaches of the Willamette River serve all of the functions that are served by its tributaries. The whole river channel is a passageway for migrant fish and a habitat for resident species. Recreational use of the Willamette includes water-contact activities as well as boating, fishing, and bankside pursuits, even though most of the middle Willamette is characterized by bacterial concentrations well above 1,000 MPN. The recreational potential of the central stretch of the Willamette must be viewed as particularly important, in view of the limited availability of water recreation sites in the shallow, turbid tributaries of that portion of the river. At the present time, Corvallis and Adair Air Force Base are the only communities to draw water from the Willamette; but future growth and low summer flows may make it increasingly necessary for communities along the river to turn to the Willamette for water supplies. It is, in any case, the most convenient source. The neglect of the Willamette as a source of water supplies may be traced historically to the ready availability of exclusive, protected sources. At the present time, however, it is probable that the main obstacle to using the Willamette as a source of municipal water is the aesthetic objection to using a water supply that is generally considered to be polluted. For most of the river, this

assumption of pollution has no basis in fact, but it remains a very real socio-psychological obstacle to securing an optimum solution to water supply problems. Other uses of the central portion of the Willamette River, which are economically significant but have limited quality needs, include navigation and irrigation.

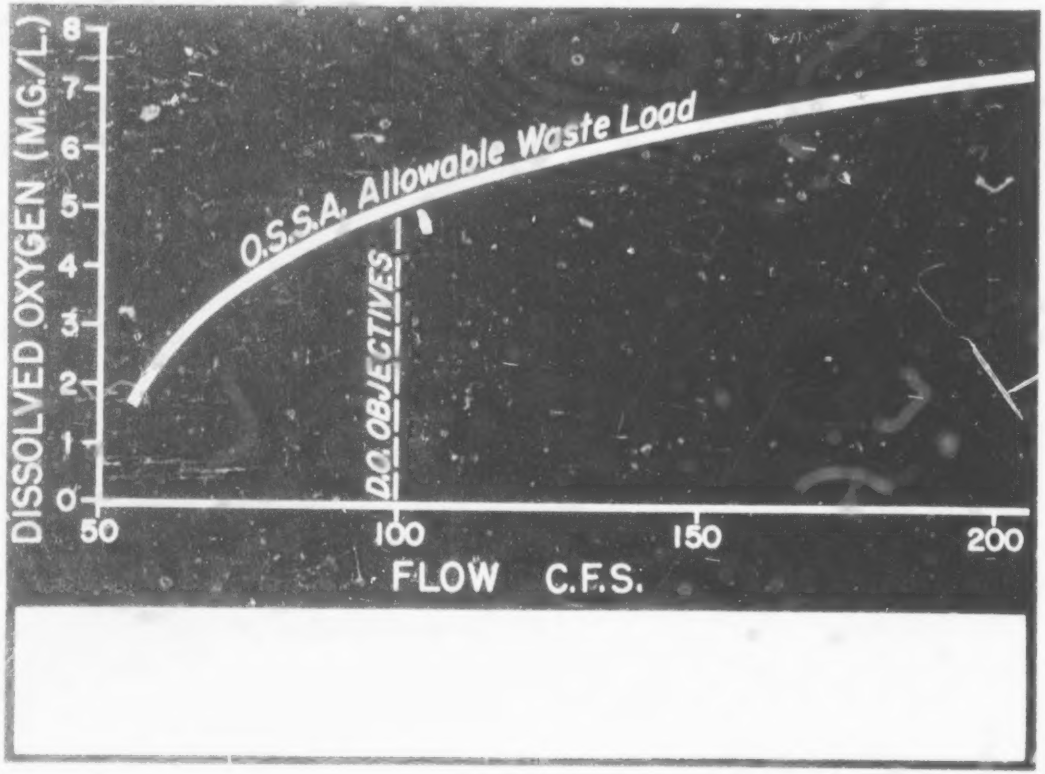
Because of the nature of uses, the primary water quality objectives for the middle Willamette Basin are those relating to dissolved oxygen, temperature and bacteria. Maintenance of a dissolved oxygen level of 7 mg/l in all waters of the region which are not otherwise unsuitable by reason of temperature is necessary to fish production. Those areas—such as the lower stretches of Marys River, the Luckiamute River, Rickreall Creek, the Pudding, Yamhill and Calapooia Rivers—in which summer temperatures customarily exceed 70 degrees require at least 5 mg/l of dissolved oxygen in order to accommodate fish passage needs. If temperature benefits can be obtained in planned reservoir projects on the Yamhill, Calapooia, and Pudding Rivers, the 7 mg/l dissolved oxygen objective should be adopted for the area that is benefited. All reaches of all streams providing water contact recreation should maintain bacterial concentrations of less than 1,000 MPN. Attainment of this objective on the Willamette River proper is particularly to be desired, because of the river's high potential for filling the middle basin's obvious deficiency of water recreation opportunities, and because of the concentration of population along its banks.

QUALITY MANAGEMENT PROGRAM

Maintenance of water quality sufficient to serve uses which occur in the middle Willamette and restoration of the limited areas of degraded water quality are largely dependent on installation of superior waste treatment and control measures.

The over-riding need in this regard is for facilities providing the equivalent of chemical recovery by Publishers Paper Company at its Newberg pulp mill, together with primary treatment for the pulp and paper mills at Salem, Lebanon, and Newberg. This, with completion of Corvallis' secondary treatment plant and adequate storage of residual pulp and paper mill wastes, should be sufficient in the short run to limit the major problems of pollution on the South Santiam, high bacterial concentrations on the Willamette, and the degradation of water quality that occurs in the Newberg pool.

There are additional treatment requirements which are less pressing in terms of significance to an immediate solution of Willamette water quality problems, but which represent needed additions to the pollution control facilities of the area. These include secondary waste treatment



for the Lebanon pulp and paper mill, provision of capabilities for evaporation and burning of pulping liquors at the Salem pulp mill, enlargement of the Sweet Home, Mt. Angel, Dallas, and McMinnville plants, and installation of secondary treatment at Independence. Ultimately, secondary waste treatment must be required of all of the pulp and paper mills. The practice of treating municipal and industrial wastes in a common waste treatment plant, which is well established in the area, is sound and should be continued.

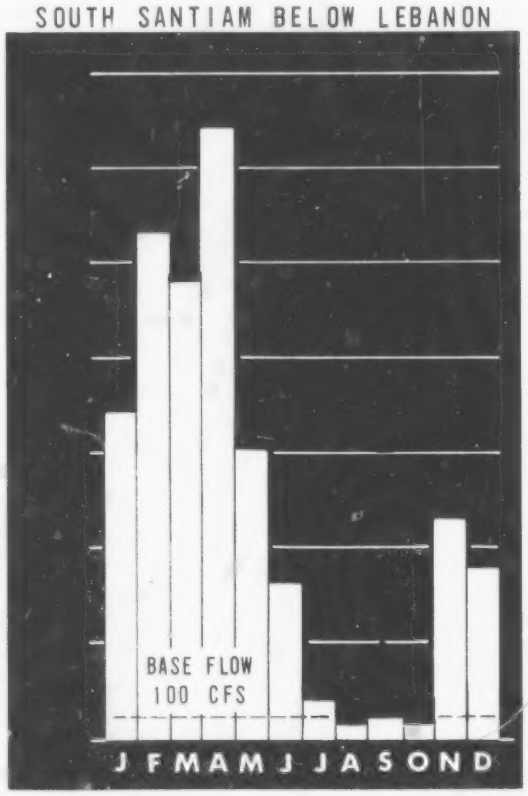
At several points in the middle Willamette, water quality can be distinctly improved by using reservoir storage to regulate flows in a manner that augments the streamflow normally available in summer months. Under the Federal Water Pollution Control Act, storage to provide such flow regulation is a legitimate function of Federal reservoirs, when adequate waste treatment is practiced within the watershed.

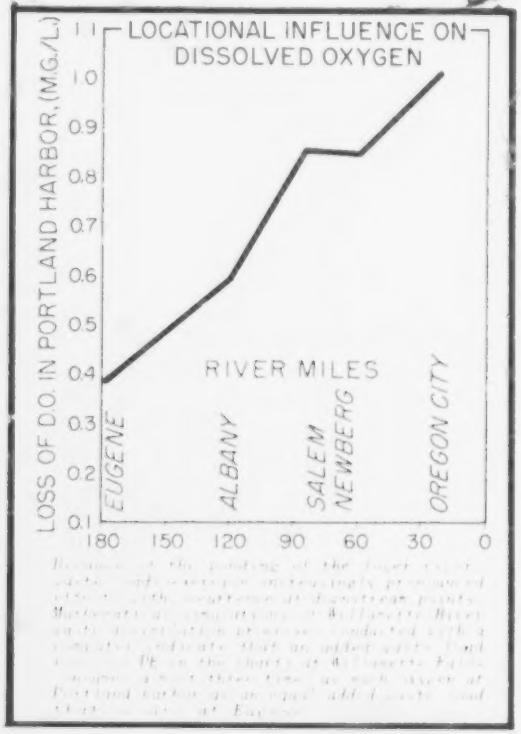
Flow regulation for quality control is essential in the South Santiam if dissolved oxygen is to be maintained at the 5 mg/l objective deemed necessary for the passage of salmonid fish. If one assumes that the requirements of the OSSA--secondary treatment of municipal wastes and limitation of the waste discharges of the Crown Zellerbach pulp and paper plant to 5,000 PE--constitute adequate treatment, it is necessary to maintain a flow of 100 cfs at Lebanon in order to provide the required oxygen objective. Experience of the 1944 design year indicates that an average flow deficit of about 37 cfs may be expected to occur in August, about 22 cfs in October. With storage of about 3,540 acre-feet in Green Peter Reservoir available to even out summer flows at the base level of 100 cfs, the proper dissolved oxygen objective can be attained.

Buckreall Creek dries up entirely in a dry year; and calculations indicate that a flow of 13 cfs is required to maintain a dissolved oxygen level required to sustain fish passage in the stream. To provide that level of flow over four months storage of 3,120 acre-feet can be incorporated for quality control in the proposed Monmouth-Dallas project.

The Pudding River suffers severe dry year summer flow curtailment, resulting in dissolved oxygen drawdowns harmful to fish life. Several project sites along the Pudding are being studied, and any storage built upon the river system should, in the interests of good practice, provide a dependable flow of 55 cfs at Mt. Angel in order to maintain a dissolved oxygen level of 5 mg/l. Based on conditions that obtained during the 1941 water year when average monthly flow varied from 18 cfs in August to 47 cfs in July, with the flow deficiency extending into September and October, a total of 6,360 acre-feet of active storage would be required to maintain desired water quality. Such flow augmentation would not only benefit the Pudding but would be of minor assistance in alleviating the pollution problem that occurs in Portland harbor, as would the flow regulation proposed for the South Santiam River.

A problem occurs in all of the streams which serve extensively as a source of irrigation water. There are in many cases sufficient flows at gaging points to provide the quality objectives set by fishery and waste assimilation needs; while flows between gaging stations drop well below such levels as a result of irrigation withdrawals, then subsequently recover as a result of irrigation returns. It is essential, if water quality is to be maintained, that base flows be established and protected against such withdrawals. Thus, a flow stated to be required for quality control purposes must be considered as the minimum allowable flow throughout a reach of the river--in the case of the Pudding, from Mt. Angel to the mouth, in the South Santiam, from Lebanon to the mouth. In the Yamhill River, for example, a base flow of 35 cfs is necessary to maintenance of a dissolved oxygen objective of 5 mg/l. Present flows generally remain above this level--except in the case of irrigation diversions. Increased irrigation however could result in a level





of flow well below that necessary to provide a satisfactory dissolved oxygen level. It is essential, then, that any increase in irrigation proceeding from completion of the U. S. Bureau of Reclamation's Red Prairie project not impinge upon summertime flows to the extent that they drop below 35 cfs.

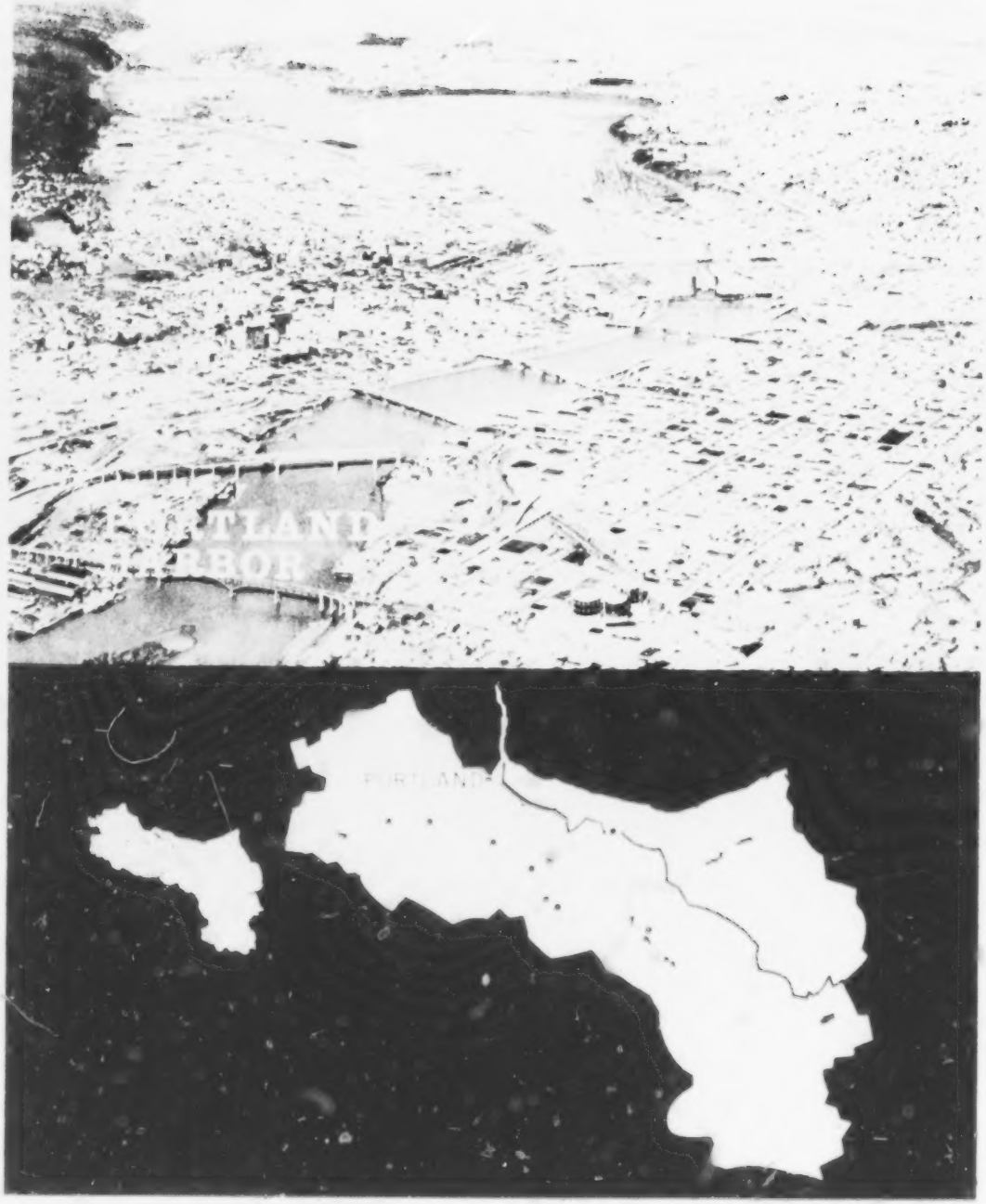
Because of the widespread prevalence of turbidity in the middle Willamette watercourses, measures to control erosion should be aggressively promoted. The natural turbidity that is due to bank caving and natural runoff may be controlled to some extent by channel improvements. Because of the prevalence of agriculture in the area--cultivated fields occupy most of both banks of the Willamette and the lower stretches of tributaries through the middle basin--agricultural practices which reduce wind and water erosion of soils are of great importance to the water quality. In headwaters, logging practices, particularly the road construction that accompanies extension of logging, should be strictly regulated in the interest of erosion control. On National Forest land a system of procedural guarantees should be incorporated in all cutting contracts. In the case of privately owned forest lands, it would be well to extend the authority of the OSSA to include inspection of logging practices. Construction and gravel-washing operations, too, should be reviewed by the Sanitary Authority. The agency should be vested with power to issue abatement orders and impose sanctions in the event that normal practice unduly increases turbidity. In addition, careful monitoring of procedures employed in spreading fertilizers and chemical poisons should be conducted by the OSSA; and the U. S. Department of Agriculture should diligently fulfill its responsibilities with regard to determining optimum procedures and application rates for such materials--optimums that should balance water quality considerations with productivity and other factors affecting the uses of such materials.

A major means of alleviating pollution of the Willamette in a manner which lessens the cost of waste treatment, storage for flow regulation, or other methods of accomplishing a reduction of the effects of wastes, is to limit expansion of industries which are major producers of organic wastes to the reaches of the Willamette above Salem. By increasing the degree of natural assimilation of wastes which occurs before the river begins to pool near Newberg, the procedure would derive a higher average water quality for the Willamette River as a whole from the same level of waste abatement measures.

Intimate knowledge of the river system and of wastes entering it is an essential part of controlling water quality. It is necessary that flows, waste loads, and water quality be regularly measured, analyzed, and the data available for use. To provide a sufficiently close knowledge of the middle Willamette, the OSSA should continue its program of making spot summer samplings of water quality. The FWPCA should establish a water pollution surveillance system station at Corvallis, in order to measure the quality of the Willamette's waters upstream of the monitors in the lower reaches of the river. Flow data for tributaries below Salem are inadequate for the level of intensive pollution control management that will become necessary as waste loads and the degree of flow regulation increase. Additional flow gaging stations are required on the Pudding, Molalla, and Yamhill Rivers. To supplement the knowledge that such a reporting system would provide, and to furnish the data neces-

Lower Willamette

SITUATION



Oregon and part of Washington. Diversified manufacturing and service industries characteristic of regional center are the foundation of the area's economy, accounting for about 85 percent of the total employment. Chemicals, metal fabrication, and electronics are large and growing industries in the Portland area; but wood products, food processing, and pulp and paper are also significant industries, particularly from a waste standpoint. Over two-thirds of the total Willamette Basin's food processing employment is centered in the lower Willamette and Tualatin areas; and two pulp mills at Oregon City and West Linn produce almost a third of the total Willamette Basin pulp and paper output.

Population of the lower basin in 1960 was 711,000--about 61 percent of that of the entire Willamette Basin. The Portland service area, which includes such outlying communities as Beaverton, Forest Grove, Hillsboro, Gresham, West Linn, and Oregon City, made up almost 95 percent of this total and is expected to continue to be the nexus of future population growth in the entire basin and the State. By 1985, population is projected to double, with almost all of the growth occurring in the Portland area; by the end of the study period, the population of the lower basin is expected to be over 2.1 million and a major source of organic waste.

Water resources within the area include the Willamette, Tualatin, Clackamas, and Sandy Rivers. These streams are a study in contrast; the main stem below Willamette Falls and the lower Tualatin are sluggish streams of very flat gradient while the Clackamas and Sandy Rivers are characteristic mountain streams--flowing swiftly over rocky beds and steep slopes. Because of its physical conformation, the Clackamas has been well developed for hydro-power by Portland General Electric Company. The river system includes five reservoirs which provide recreational opportunities and the possibility of low flow regulation. The only other development in the lower basin is the Bull Run Reservoir in the Sandy Basin, from which Portland obtains its water supply. Scoggins Reservoir, a Bureau of Reclamation project on the Tualatin, has been authorized for construction and will provide a usable storage of about 53,000 acre-feet.

The quality of the Clackamas and Sandy Rivers is excellent except for seasonal turbidity during winter floods. There are no major waste discharges to the Sandy, and the only municipalities on the Clackamas--Estacada and Sandy--provide waste collection and secondary treatment facilities. Throughout the rest of the basin, however, the most severe water quality degradation in the entire Willamette Basin occurs--due partially to hydraulic characteristics which prevent adequate reaeration, low summer flows, and partially to high waste loading and unfortunate industrial location.

Of primary concern in the lower Willamette and Tualatin Rivers is the drop in dissolved oxygen concentration which occurs during the summer low flow season, in the Portland harbor--the passageway for all migratory fish in the Willamette system--summer dissolved oxygen levels average from 3 to 4 mg/l. During exceptionally dry summers (such as 1965 and 1966) concentrations fall below 2 mg/l for varying periods. The section of the river from Willamette Falls to the mouth ("Portland harbor") also experiences high MPN's--averaging well above 1,000. Water temperatures in summer average in the low 70's, with occasional readings of over 80 degrees. And floating and suspended solids create unsightly and foul-smelling rafts which destroy the aesthetic beauty of the river.

Quality of the upper Tualatin is generally satisfactory from a chemical, physical, and biological standpoint. During low flow, however, lower reaches of the river have excessive suspended and floating solids, coliform counts averaging over 1,000 MPN, nuisance aquatic growths, dissolved oxygen averaging 1.0 mg/l, and peak temperatures exceeding 80 degrees.

Wastes produced in the lower Willamette constitute over 45 percent of the total oxygen-demanding strength of all wastes discharged to the Willamette River system. The principal sources are pulp and paper manufacture and municipal wastes. The total estimated organic waste load produced in the lower Willamette is about 2.75 million PE, which is reduced during the critical period to about 0.8 million PE by waste treatment or other means of waste reduction.

The principal waste sources of the area--and the most significant of the entire Willamette drainage because of their disastrous effect on the dissolved oxygen balance in Portland harbor--are the Crown Zellerbach and Publishers Paper mills at West Linn and Oregon City. The two mills produce over 2.0 million PE of untreated waste--almost 75 percent of the lower basin waste load and about a third of the total Willamette Basin waste output. Both mills utilize the sulfite pulping process.

The waste treatment practices of these two mills must be considered unsatisfactory. Neither of the mills provides waste treatment. Instead, they effect a reduction of about 75 percent in strength of waste discharge during the summer critical periods; Crown Zellerbach by storage in holding lagoons with discharges made during higher flows; Publishers Paper by barging wastes to the Columbia River. The OSSA has instructed

WILLAMETTE R.

INVENTORY OF MAJOR WASTE SOURCES

LOWER WILLAMETTE RIVER BASIN

July 1965

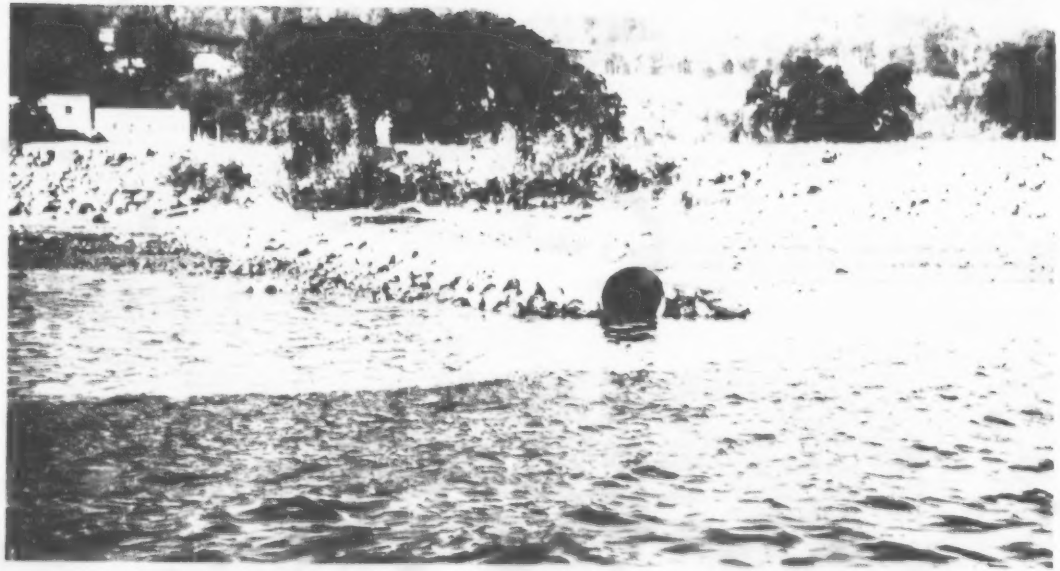
Watercourse Community or Industry	River Mile	Pop. Served	Untreated Waste PE	Treatment	Capacity Design PE	Const. Date	Discharged Waste PE	Project Needs	Status of Improvement
Tualatin	29								
Forest Grove	55	6,000	61,000	Secondary	90,000	1965	4,200	None	--
Forest Fibre Products		--	78,000	Land	--	--	0	Impr. Oper.	None
Cornelius	50	1,000	1,200	Secondary	2,500	1959	150	None	--
Hillsboro #1	44	5,000	9,000	Secondary	5,000	1936	2,100	Replace	Preliminary plan
Rock Creek	38								
Somerset West	8	640	800	Secondary	1,600	1964	120	None	--
Beaverton Creek	5								
Cedar Hills	7	7,600	9,300	Secondary	13,000	1962	1,400	None	--
Beaverton	6	9,500	14,500	Secondary	14,000	1963	2,300	None	--
Tektronix, Inc.	5	1,500	1,800	Secondary	4,000	1963	270	None	--
Cedar Mill Creek	4								
Sunset Valley S.D.	3	4,800	7,400	Secondary	10,000	1965	1,255	None	--
Aloha S.D.	1	6,350	8,000	Secondary	12,000	1965	1,000	None	--
Hillsboro #2	1	4,500	6,000	Secondary	10,000	1959	1,200	None	--
Chicken Creek	16								
Cedar Creek	3								
Sherwood	1	700	6,600	Secondary	5,500	1965	1,800	None	--
Fanno Creek	9								
Fanno Creek S.D.	7	16,000	16,200	Secondary	15,000	1961	2,550	Enlarge	Final plan
Tualatin Hills	5	1,200	1,200	Secondary	1,400	1962	180	None	--
Tigard	3	2,300	6,000	Secondary	5,600	1965	600	None	--
West Linn #2	28	1,500	1,500	Secondary	2,500	1963	300	None	--
Crown Zellerbach	26	--	1,172,000	Holding pond	--	--	342,600	Recovery Primary Secondary	Preliminary primary plan
Publishers Paper Co.	26	--	882,000	Barging	--	--	172,700	Recovery Primary Secondary	Preliminary primary plan initiating in-plant changes
Oregon City	25	12,000	21,000	Secondary	56,000	1964	3,150	None	--
Clackamas River	25								
Estacada	23	1,000	1,000	Secondary	2,500	1963	150	None	--
Tickle Creek	15								
Sandy	10	1,200	1,200	Secondary	1,500	1965	180	None	--
West Linn #1	24	3,000	3,000	Secondary	7,000	1963	450	None	--
Marylhurst	22	600	600	Secondary	1,100	1962	200	None	--
Oaklodge	21	13,000	13,000	Secondary	12,000	1961	1,900	None	--
Tryon Creek	21	8,000	10,000	Secondary	31,000	1965	3,100	None	--
Milwaukie	18	10,000	10,000	Secondary	14,000	1962	1,500	None	--
Portland	--	370,000	385,000	Primary	500,000	1962	(260,000)*	Expansion	Final plan
Portland waterfront	--		28,000	None	--	--	28,000	Intercept	Final plan

*To the Columbia River.

these mills to provide primary treatment by 1968, and has assigned each mill an allowable low flow discharge limit. This schedule sets the upper permissible limit of discharge as 90,000 PE per day for Publishers Paper and 120,000 PE per day for Crown Zellerbach at West Linn. Present OSSA policy permits storage of wastes during low flows as a substitute for treatment beyond the primary level.

The effect of their wastes on water quality is augmented considerably by the location of the two mills. The stream does not reach Willamette Falls with adequate oxygen content to assimilate the heavy waste discharges there. Residual loads from upstream deplete oxygen levels, and only minor reaeration is possible through the sluggish 25-mile Newberg pool before wastes at Oregon City and West Linn are discharged to the stream. During low flow months, nearly all of the river is diverted from the falls through power turbines, precluding reaeration. Below Willamette Falls, the stream gradient is extremely flat, and at times, tidal influences affect the assimilative and recovery potential of the stream. Flow in the harbor is periodically reoded by high river stages of the Columbia, so that during low flow periods, the lower river is very sluggish, and may even experience flow reversal for short periods of time. Because of these undesirable flow characteristics, future development of organic waste producing operations should be encouraged to locate well above Salem.

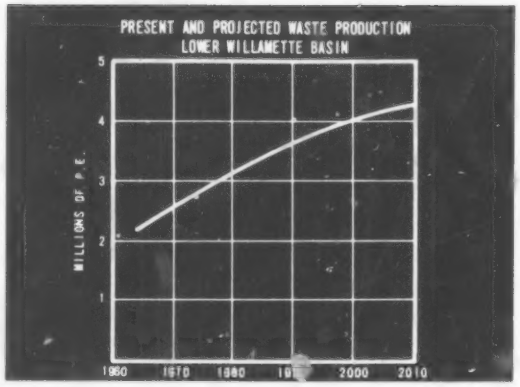
As opposed to the pulp and paper industry, the food processing industry, which, in the lower Willamette, is treated through municipal systems, and municipalities have done an excellent job of reducing wastes. Despite the fact that the Willamette flows through the



heart of Portland. Municipal waste loads to the river are comparatively minor. Effluents from adequate secondary treatment plants serving six communities between Milwaukie and West Linn discharge about 8,000 PE to the lower Willamette. Most of the municipal wastes of Portland are treated in a primary plant which discharges to the Columbia River where they have no effect on the qualities of the Portland harbor. There are however numerous discharges from private and storm sewers that are estimated to have a total strength of about 28,000 PE, flowing directly into the harbor. The city of Portland, which had previously completed construction of a master interceptor sewer system and treatment works pursuant to the OSSA's orders, is currently in the sixth year of a program to complete interception of these waste sources.

An additional source of sanitary waste in the lower Willamette is the armada of houseboats that anchor along the Willamette from Oregon City to the mouth. These seemingly insignificant dischargers are of deep concern to regulatory agencies because they provide no treatment to their wastes. Efforts are currently being made by the FWPCA laboratory at Corvallis to quantify these waste discharges. A similar area of concern is the sanitary and industrial wastes discharged by coastal ocean-going vessels in Portland harbor.

Wastes produced in the Tualatin River basin total over 250,000 PE, almost entirely from food processing and municipalities. All communities provide secondary treatment and several industries use land irrigation so the total strength of waste discharge to the Tualatin and tributary streams is only about 20,000 PE—a reduction of over 90 percent. Low flow and flat gradient (less than one



foot per sq/sec combine to make water quality management of the Tualatin the most difficult of that of any Willamette tributary. Rapid suburban population growth and a multiplicity of governmental entities with responsibility for waste treatment (3 counties, 12 cities, 38 sanitary districts, and numerous industries) complicate an already difficult situation.

The extremely high level of waste treatment has been necessary to maintain even a moderate level of quality in the lower Tualatin. During recent years, summer streamflows in the main stem have been less than 25 cfs—a good portion of it irrigation return flows and treated sewage flows. Profuse algae and slime growths fostered under these conditions destroy the beauty of the river and cause nuisance odors. During the past eight years, the various municipalities in the basin have upgraded their waste facilities to help alleviate these problems.

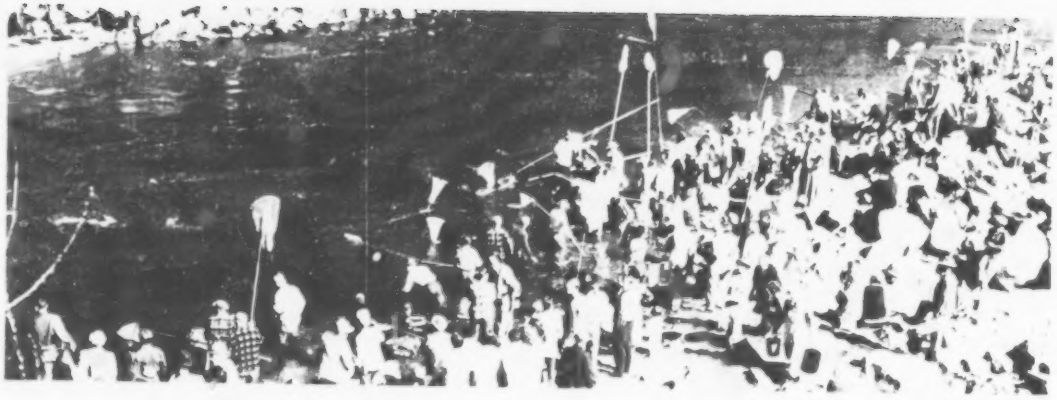
Raw waste loads of 565,000 PE are projected to occur by 1985, and a continuing high degree of waste treatment by municipalities and industries will be necessary. The OSSA has adopted a policy of no less that 90 percent reduction of wastes into the Tualatin system. In addition, a basin-wide plan for the collection and treatment of wastes has been developed and is currently being restudied to better meet the challenge of future waste disposal. But even advanced waste treatment will not achieve and maintain adequate water quality under future waste loading conditions unless minimum regulated streamflows are made available to receive and assimilate treated waste discharges.

Wastes produced in the lower Willamette are expected to increase at a moderate rate, with total waste production in 1985 forecast to total about 3.4 million PE; this increase is expected to develop mainly from food processing and municipal growth. The pulp and paper industry is expected to increase by only about 10 percent.

WATER USES AND QUALITY OBJECTIVES

As in the upper and middle basins, the principal quality-demanding uses of water in the lower Willamette are the passage of salmonid fish, municipal and industrial water supply, and recreation. Navigation is a significant use in the lower main stem, but irrigation demands are slight.

The Clackamas is used extensively for water supply, power, salmonid fish production, and water recreation of all types. Currently, the communities of Oregon City, West Linn, and smaller areas supplied by water districts obtain municipal supplies from the Clackamas. Future municipal demands in the lower basin may necessitate additional development of supplies on the Clackamas because of its excellent quality and the absence of waste discharges to the stream. As a spawning and rearing ground for salmonid fish, the Clackamas is second only to the Mckenzie in the entire Willamette system. Plentiful numbers of rainbow, Dolly Varden, and cutthroat trout, as well as a large percentage of the basin's anadromous salmonids grace these sparkling clear waters and provide the most extensive sport fishery in the lower basin. The Clackamas watershed is



probably more intensively used for sport fishing and camping than any other in the Willamette system because of its proximity to the Portland urban area.

Similar to the Clackamas in every respect, the Sandy River provides the same water uses. The Sandy provides more recreational development than the Clackamas, however. Two State parks--Dabney and Lewis and Clark--have annual attendance figures well over half a million people and show continually increasing trends. The basin contains the largest single water supply development in the entire Willamette--Bull Run reservoir which supplies Portland. As in the Clackamas, excellent water quality serves to promote all water uses, rather than inhibit them as is true of quality in the rest of the lower basin.

Water uses of the Tualatin and its tributaries have been severely impaired during summer low flow conditions. The upper reaches of the basin support a substantial salmonid fishery, but anadromous fish must pass through a section of the lower main stem which experiences extremely low dissolved oxygen concentrations and high water temperatures in the summer. These conditions have severely reduced fish runs, and have practically eliminated the resident salmonid fishery. Only scrap fish can survive the summer quality degradation. The basin is one of the residential areas supporting the Portland *service area--the site* of intense water-oriented recreation and riverside homes. Not only are the aesthetic values of the stream destroyed by nuisance aquatic growths, but swimming and other water sports are being curtailed each summer because of the high MPN values that accompany depressed streamflows. Commercial swimming establishments in the lower Tualatin have been periodically closed by the Oregon State Board of Health. Irrigation is a significant water use on the Tualatin and is expected to increase. In fact, irrigation return flows bearing high quantities of nutrients make up a substantial portion of the summer flow.

In terms of quality needs, the principal water use of the lower main stem Willamette, or Portland harbor, is the passage of migratory fish to the tributary spawning and rearing areas of the Willamette Basin.

Oxygen levels in the harbor during the months of June, July, August, and September fall below anadromous salmonid requirements, and thus block, or at best inhibit, the passage of these species through the lower Willamette.

Other than fish passage, the lower Willamette is used extensively for navigation--both by large commercial vessels and by forest products industries to move logs. Because of bacterial pollution throughout this stretch, there is only limited water-contact recreation, although pleasure boats and some water skiers use the stream. Public beaches along the lower Willamette, like the Tualatin, have been closed by the State Board of Health because high MPN values pose a threat to public health. As a source of municipal water supply, the lower Willamette has traditionally been bypassed by adjacent communities in favor of water from protected supplies, in spite of higher costs for transmission.

Because of the nature of uses, the primary water quality objectives for the lower Willamette Basin are those relating to dissolved oxygen, temperature, and bacteria. Maintenance of at least 7 mg/l dissolved oxygen, and saturation where possible, in the entire Clackamas and Sandy and in the reach of the Tualatin above Rock Creek (RM 38) is required for anadromous fish spawning. In those areas where summer temperatures and hydraulic characteristics make such an objective unreasonable, a minimum of 5 mg/l must be maintained to permit anadromous fish passage to higher quality tributaries. Such areas in the lower Willamette include the Tualatin below Rock Creek and the main stem Willamette.

Temperature criteria for anadromous fish life in the lower Willamette and Tualatin Rivers is 70° F; it should be realized, however, that such a temperature level will be difficult to maintain in the lower Tualatin without substantial increases in flow. All reaches of all streams providing water-contact recreation should maintain bacterial concentrations of less than 1,000 MPN. Attainment of this objective in the lower Willamette and lower Tualatin will help to realize the recreation potential of the lower basin--a resource which for decades has suffered because of poor water quality.

Although no specific objective can be set to eliminate slimes and nuisance growths, reduction of nutrients and settleable solids must be effected in the lower Tualatin and lower Willamette in the interest of reducing such growths.

QUALITY MANAGEMENT PROGRAM

Maintenance of water quality to serve the various uses of the lower Willamette is largely a matter of providing better waste treatment and control, which must be supported by flow regulation.

The most immediate need in the lower basin is the installation of facilities providing the equivalent of primary treatment and chemical recovery by Publishers Paper Company at Oregon City and Crown Zellerbach Corporation at West Linn. As an interim measure, adequate storage of residual pulp and paper wastes must be used in times of low flows to protect summer water quality. This measure must be considered as merely a temporary solution. Within the near future, primary and secondary treatment will be required of both mills if the water quality problems in Portland harbor are to be alleviated. There are additional treatment requirements which are less urgent in terms of significance to an immediate solution of Willamette quality problems. These include the replacement of the Hillsboro No. 1 plant--built in 1936 and currently overloaded--and an enlargement of the Fanno Creek Sanitary District plant.

The Tualatin River Basin is subject to unusually stringent treatment requirements. Although the basin's wastes are currently reduced at least 90 percent by treatment, it appears that advanced waste treatment will ultimately be required to correct the severe quality degradation in the lower Tualatin, even with flow regulation.

At several points in the lower Willamette Basin, water quality can be significantly improved by using storage to regulate and augment summer flows. Flow regulation for quality control is essential in the Tualatin if dissolved oxygen levels are to be maintained at 5 mg/l in the lower reaches. If the requirements of the OSSA--no less than 90 percent reduction of municipal and industrial wastes--constitute adequate treatment, it is necessary to maintain a flow of 260 cfs at Farmington to provide the required oxygen objective. Based on the 1911 de-

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sign year, average flow deficits of about 159, 205, 210, and 197 cfs could be expected to occur in the months of July, August, September, and October, respectively. Storage of about 40,000 acre-feet is needed to maintain summer flows at the 260 cfs base level. About 10,000 acre-feet of this storage has been recommended for quality control in the Scoggins Creek project of the Bureau of Reclamation. The remaining 10,000 acre-feet could be made available from other storage sites under study in the upper Tualatin Basin.

The Portland harbor requires augmented summer flows to maintain 5 mg/l dissolved oxygen concentrations needed for fish passage. Under the OSSA's current policy of requiring basic side secondary treatment for all wastes, a base flow of 6,000 cfs at Salem will maintain this objective under both present and projected 1985 waste loading conditions. After 1985, additional treatment may be required if a higher base flow is not established. Based on the design year (1944) average deficits of 1,200, 2,770, 2,850, and 2,910 cfs may be expected to occur in July, August, September, and October, respectively. A total of 584,000 acre-feet of storage is needed to provide a base flow of 6,000 cfs at Salem and maintain an objective of 5 mg/l in the harbor. Such storage is available in existing and planned Willamette Basin reservoirs.

Effective land management practices are particularly important in the Tualatin Basin, and measures to control erosion should be aggressively promoted throughout the lower Willamette to reduce turbidity. The importance of agriculture in the Tualatin--cultivated fields with extensive irrigation occupy most of the lower basin--makes application of practices to reduce wind and water erosion a necessity, especially since irrigation return flows make up a large portion of the existing Tualatin streamflows. In the headwaters of all tributaries, logging practices, particularly logging road construction, must be strictly regulated in the interest of erosion control.

Because hydraulic characteristics of the Willamette River below Willamette Falls reduce the capacity of the stream to assimilate wastes, expansion of industries characterized by high volumes of organic wastes might best be limited to reaches above Salem.

Urban runoff is more significant in the lower basin than other sections of the Willamette. Sewers in the Portland service area combine sanitary and storm-water waste transmission functions which on occasion result in treatment plant overloadings and the bypassing of wastes directly to the watercourse. Consideration should be given to two alternative methods of handling this problem: (1) separation of combined sewers, or (2) provision for storage basins in the system to temporarily reduce high flows to treatment plants.

Control of untreated sanitary wastes from houseboats may be accomplished by interception and pumping to municipal treatment plants or by individual treatment units on each boat. The Oregon statutes require adequate treatment before discharge of houseboat wastes; the OSSA and the Board of Health have responsibility for this program. By 1967, all such wastes should receive adequate treatment. Discharges from ocean-going vessels in Portland harbor are the responsibility of the U. S. Coast Guard. Studies are in process to determine techniques of control for these wastes.

In addition to treatment and flow regulation, the lower Willamette offers the possibility for the use of two other techniques to improve water quality. The first of these is through aeration of the lower Willamette, either mechanically, in Portland harbor, or naturally, at Willamette Falls. By allowing the stream to pass over the falls, instead of through turbines during the critical period, natural reaeration would add dissolved oxygen to the river before it reaches Portland harbor. Alternatively, theoretical estimates indicate that at least half a milligram per liter of dissolved oxygen can be added at the point that oxygen concentrations sag to 5 mg/l with mechanical aerators.

The second technique is the collection and transport of wastes out of the basin to a place where their influence would be lessened. This is particularly applicable in the case of the Tualatin Basin, where advanced waste treatment requires the assistance of large-scale flow regulation to provide a suitable level of dissolved oxygen in the lower river.

Any or all of the management techniques discussed in this section require an intimate knowledge of the river system, its waste loads, and its quality. Such information should be provided by a program of monitoring and data reporting. At the present time, such a system is provided in the form of three continuous automatic monitors maintained by the FWPCA in Portland harbor, and by daily to weekly sampling conducted in summer in the Willamette and its tributaries by the OSSA. Amplification of the quality sampling by flow data--including measurement of flow at the mouth of the Tualatin, Clackamas, and Willamette Rivers--and by regular reporting of waste discharges would provide tools for effective management of the watershed for pollution control. Waste discharges reported should include those of the Publishers Paper Company and Crown Zellerbach Corporation pulp and paper mills, and all waste treatment plants operating in the lower basin.